LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA26 | Washwood Heath to Curzon Street

Flood risk assessment (WR-003-026)

Water resources

November 2013

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Department for Transport

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Appendix WR-003-026

Environmental topic:	Water resources and flood risk assessment	WR
Appendix name:	Flood risk assessment	003
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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise six parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Additional specific appendices for each community forum area are also provided. For the Washwood Heath to Curzon Street area (CFA26) these are:

- a water resources assessment (Volume 5: Appendix WR-002-026);
- a flood risk assessment (i.e. this appendix);
- a hydraulic modelling report for the River Tame (Volume 5: Appendix WR-004-019);
- a groundwater modelling report for the Bromford tunnel portals (Volume 5: Appendix WR-004-020); and
- a hydraulic modelling report for the River Rea (Volume 5: Appendix WR-004-021).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5 water resources map book.

1.2 Scope of this assessment

1.2.1 The flood risk assessment (FRA) considers the assessment of flood risk in the Washwood Heath to Curzon Street area. This FRA is based on the Proposed Scheme as shown Volume 2: Map book CT-06. Its purpose is to document how flood risk has been assessed and managed at this stage of the project's development so as to inform the hybrid Bill. It can be anticipated that the details of flood risk management will develop further as the project proceeds through later stages of design. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.3 Location

1.3.1 The Washwood Heath to Curzon Street area (Figure 1) covers a 5.7 km section of the Proposed Scheme in Birmingham, to the east of the city centre. It extends from the A4040 Bromford Lane in the east to Moor Street Queensway, on the eastern edge of Birmingham city centre, in the west. The area includes the Birmingham City Council (BCC) wards of Hodge Hill, Washwood Heath, Saltley, Nechells and Ladywood.

[1] Department for Communities and Local Government (2012) *National Planning Policy Framework*

Figure 1: Washwood Heath to Curzon Street CFA26

Legend

River network

River Type

- Main River
- Ordinary River (Secondary)
- Ordinary River (Tertiary)
- Lake / Reservoir
- Extended Culvert (>50m)
- Canal
- Canal Tunnel
- Underground River
- Route centre line
- Community forum area boundary
- Water body

0 0.125 0.25 0.5 0.75 1 Kilometers

2 Flood risk assessment methodology

2.1.1 The aim of this FRA is to assess the risk of all forms of flooding to and from the development. A risk-based methodology has been adopted through the application of the source-pathway-receptor (SPR) model.

2.2 Source-pathway-receptor model

2.2.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short-term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewer flooding) in the short or medium term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.2.2 The identification of the flooding source and pathway is based on a review of local conditions and consideration of the effects of climate change (CC).

2.2.3 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. Taking this into account, the associated magnitude of risk is then categorised.

2.2.4 Receptors include people, properties, businesses, infrastructure, the built and the natural environment which is within the range of the flood source, and is connected to the source of flooding by a pathway. The Proposed Scheme includes all associated temporary and permanent infrastructure.

2.2.5 This FRA presents baseline (current day) flood risk and post-development flood risk as a result of the Proposed Scheme. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is proposed in line with recommendations in the NPPF.

2.2.6 Existing development within the study area is identified using Ordnance Survey (OS) mapping information and a high level assessment has been undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.2.7 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. The Proposed Scheme is committed to ensuring that there is no adverse effect on the risk of flooding to third party receptors, and therefore, where such potential exists, mitigation is proposed based on further analysis.

[2] Department for Communities and Local Government (2012) *National Planning Policy Framework Technical Guidance*

2.2.8 The FRA has been written to demonstrate the relative change in flood risk as a result of the Proposed Scheme. Whilst all change in risk status is highlighted, the focus of this document is on the change in risk status to identified local receptors, particularly existing infrastructure.

2.3 Flood risk categories

2.3.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Watercourse[3]		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water / overland flow[4]	No FMfSW	FMfSW <0.3m for 1 in 200 year event	FMfSW >0.3m for 1 in 200 year event and FMfSW <0.3m for 1 in 30 year event	FMfSW >0.3m for 1 in 30 year event	
Groundwater[5]		Very low-low	Moderate	High-very high	
Drainage and sewer systems[6]	No sewer in vicinity of site	Surcharge point >20m from site and no pathways	Surcharge point within 20m of site and restricted pathways	Sewer network crosses site and pathways exist	
Artificial sources[7]	Outside of inundation mapping / no pathway exists	Within inundation mapping / pathway exists			

2.4 Exclusions and limitations

2.4.1 Temporary works have not been assessed unless they are of a significant scale compared with the post-construction scheme or are subject to or pose a significant flood risk or change in risk.

[3] River flood risk taken from the Environment Agency Flood Zone mapping or hydraulic modelling carried out for this FRA.

[4] Surface water flood risk taken from the Environment Agency Flood Maps for Surface Water (FMfSW).

[5] Groundwater flood risk taken from local flood risk assessment reports.

[6] Identified using the Severn Trent Water's assets network.

[7] Risk from reservoir flooding identified using the Environment Agency Reservoir Inundation mapping, canal flooding taken from identifying proximity of the Proposed Scheme to canals from Ordnance Survey mapping.

2.4.2 The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)8, which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

2.4.3 Updates on the river models provided by the Environment Agency for use on this project were carried out (and detailed in the accompanying hydraulic modelling report Volume 5: Appendix WR-004-019 and WR-021).Therefore, the flood mapping data provided in this FRA differs from the mapped outlines available from the Environment Agency. The updated models and flood extents should only be viewed in the context of assessing flood risk related to the Proposed Scheme.

2.4.4 This FRA (and accompanying appendices) will require updating as the design develops and a greater level of detailed data (e.g. topographical survey) become available.

[8] Department for Communities and Local Government (2012) *National Planning Policy Framework*

3 Design criteria

3.1.1 This FRA has taken account of the following documents:

- NPPF;
- Highways Agency Design Manual for Roads and Bridges (1992)[9];
- National Sustainable Drainage Systems (SuDS) Working Group Interim Code of Practice (2009)[10], and
- CIRIA Report C689 - Culvert Design and Operation Guide (2010)[11].

3.1.2 The key design criteria applied to the project are summarised below.

3.2 Summary of principle design criteria

Flood risk to third parties

3.2.2 The design has set out to avoid significant increases in flood risk to third parties, as a result of the Proposed Scheme up to and including the 1% Annual Exceedence Probability (AEP) flood event plus an appropriate allowance for climate change (cc) which has been abbreviated to 1% AEP+CC within this report.

Climate change

3.2.3 Climate change allowance is in accordance with NPPF.

3.2.4 Increases in peak rainfall intensity and peak river flow as a result of climate change have been allowed for as per the period 2085 to 2115 as defined in Table 5 of the Technical guidance to the NPPF and shown in Table 2.

Table 2: Appropriate Climate Change allowance figures for rainfall intensity and Peak River flow (Table 5 in Technical Guidance of the NPPF)

Parameter	**1990 - 2025**	**2025 - 2055**	**2055 - 2085**	**2085 - 2115**
Peak rainfall intensity.	+5%	+10%	+20%	+30%
Peak river flow.	+10%	+20%		

3.2.5 There is one departure to this; a 30% increase in flow in ungauged catchments has been used in order to account for uncertainty in flow calculations. This approach has been applied only when assessing culverts on small watercourses where no hydraulic modelling has been undertaken.

[9] Highways Agency (1992), *Design Manual for Roads and Bridges for trunk roads.*

[10] National Sustainable Drainage Systems (SuDS) Working Group (2009), *SuDS Interim Code of Practice.*

[11] CIRIA Report C689 (2010), *Culvert Design and Operation Guide*.

Freeboard at bridges

3.2.6 A minimum of 600mm freeboard above the 1% AEP+CC flood event has been allowed to the soffit of all bridges and viaducts. On main rivers, where possible, a freeboard of 1000mm has been allowed.

Freeboard at culverts

3.2.7 The freeboard provided between the 1% AEP+CC water level and the soffit of any proposed culvert is a minimum of 300mm for ordinary watercourses and 600mm for main rivers. The exception to this is where new structures are sized to match existing.

Flood protection to the Proposed Scheme rail infrastructure

3.2.8 The Proposed Scheme rail Infrastructure (including the track drainage systems) will be designed to be protected against inundation in the 0.1% AEP flood event for both river and surface water flooding. This will be achieved through ensuring either a of 1m between the rail level and the 0.1% AEP flood level, or by providing flood protection with a freeboard of at least 300mm above the 0.1% AEP flood level.

Attenuation of surface run-off

3.2.9 All drainage will be attenuated in order that peak surface run off from the Proposed Scheme in the events up to the 1% AEP+CC peak rainfall event is no greater than the existing current day baseline run-off under the same peak rainfall event.

4 Data sources

4.1.1 The following data sources have been referred to in the compilation of this document:

- Environment Agency web site; http://www.environment-agency.gov.uk/;
- reservoir flood mapping[12];
- generalised river flood mapping and flood zone (geographical boundary of river flood hazard) mapping[13] ;
- existing river models of the River Rea and River Tame;
- Birmingham City Council (BCC) Level 1 Strategic Flood Risk Assessment (SFRA), January 2012[14];
- historic flooding records[15];
- BCC Preliminary Flood Risk Assessment, May 2011[16];
- Flood map for surface water (FMfSW)[17];
- topographic survey (200mm grid resolution laser interferometry detection and ranging (LiDAR) survey, in digital terrain model and digital surface model format) and associated aerial photography;
- as built and historic drawings and land drainage records from Network Rail, BCC and others;
- evidence gathered from site visits (including photographs);
- online photographic and mapping resources (Google maps, Bing maps etc);
- Ordnance Survey 1: 10,000; 1:25,000 and 1:50,000 mapping;
- publicly available planning applications from recent developments within the area of interest;
- sewer network data from Severn Trent Water[18];
- British Geological Survey (BGS) mapping;
- geotechnical desk studies; and
- Powell et al (2000)[19]: Geology of the Birmingham area.

[12] Environment Agency (2012), *Lakes and reservoirs GIS layer*

[13] Environment Agency (2012), *Flood zone mapping GIS layer*

[14] Atkins (2012), *Birmingham City Council. Strategic Flood Risk Assessment updated*

[15] Environment Agency (2012), *Midlands Historical 1992 and 2007 flood event GIS layers*

[16] Birmingham City Council (2011), *Birmingham City Council Preliminary Flood Risk Assessment*

[17] Environment Agency (2012), *Midlands Flood Map for Surface water GIS layers*

[18] Severn Trent Water (2012), *Utilities GIS Data*

[19] Powell, JH, Glover, BW, and Waters, CN. (2000),. *Geology of the Birmingham area. Memoir of the British Geological Survey*, Sheet 168 (England and Wales).

5 The proposed development

5.1.1 The Proposed Scheme enters the Washwood Heath to Curzon Street area, after exiting the Bromford tunnel and proceeds alongside the proposed rolling stock maintenance depot at Washwood Heath. The Washwood Heath depot will be where rolling stock are stabled, serviced and maintained when not in service. The route continues west, passing under the Stechford and Aston railway line, through the western edge of Saltley Business Park, over the Grand Union Canal and under the B4114 Saltley Viaduct.

5.1.2 Past the B4114 Saltley Viaduct, the Proposed Scheme will rise, on embankment, towards Duddeston Mill Road. The route will then cross over the Birmingham and Derby railway line on a viaduct and continue to Curzon Street crossing over the Freightliner Terminal Depot, the River Rea, Erskine Street, Viaduct Street, the Birmingham to Bushbury railway line (also known as the Cross-City railway line), St James's Place and the A4540 Lawley Middleway.

5.1.3 The Proposed Scheme will arrive at the new Curzon Street station, the terminus for the Proposed Scheme. A number of buildings and structures will be demolished, including commercial buildings at the Washwood Heath and Saltley depots, Erskine Street, Inkerman Street, Lawford Close, residential properties at Common Lane, Curzon Gateway student halls of residence and the Fox and Grapes public house on Freeman Street.

5.2 Design Elements

5.2.1 To facilitate the Proposed Scheme the following design elements are required:

- high speed rail lines;
- overhead electrification gantries;
- signals;
- embanked sections of main line alignment and side road diversions;
- sections in cutting of main line alignment and side road diversions;
- viaducts and overbridges spanning urban areas, rural land, highways, railways, watercourses and canals;
- bridges under existing urban areas, rail and highway infrastructure;
- flood relief culverts;
- culverts for existing watercourses;
- river diversions;
- Bromford tunnel;
- drainage infrastructure;
- Washwood Heath depot; and
- Curzon Street station.

5.2.2 Within Washwood Heath to Curzon Street area the following elements have direct relevance to the assessment of flood risk:

- Curzon Street station;
- surface water drainage;
- new drainage provision for highway diversions at:
  - A4540 Lawley Middleway roundabout;
  - B4114 Saltley viaduct;
  - Pennine Way leading to Dorset Road; and
  - Aston Church Road;
- the redesign of B4114 Saltley Viaduct area which entails the road viaduct crossing the River Rea, the existing Network Rail infrastructure, the Proposed Scheme and the Grand Union Canal;
- diversion of the River Rea Overflow Channel;
- the relative level of the Proposed Scheme north of B4114 Saltley Viaduct up to and including Washwood Heath depot ;
- Washwood Heath depot ;
- diversion of Washwood Heath Brook;
- construction of shallow tunnel crossing the River Tame and associated river reconstruction and protection works; and
- a tunnel allowing the Proposed Scheme to run under the River Tame.

6 Existing flood risk

6.1 Existing flood risk

River flood risk

6.1.2 Within the Washwood Heath to Curzon Street area, river flood risk (the risk of flooding posed by rivers and stream) is dictated by the River Rea, River Tame, and interaction of these and their tributaries.

River Rea

6.1.3 The River Rea is a major tributary of the River Tame and drains south-west Birmingham and the surrounding rural areas with a total catchment of 87km^2 [20].

6.1.4 It is a main river and therefore regulatory control is with the Environment Agency, although riparian landowners do have a responsibilities to manage the river where it passes through their land and are restricted on what activities they can perform within or adjacent to the river without consent from the Environment Agency..

6.1.5 In the vicinity of the Proposed Scheme, the River Rea is culverted for approximately 310m from A4540 Lawley Middleway to a location north of the Freightliner Terminal Depot. When it emerges from this culvert, it flows within a brick lined channel through an urbanised industrial area of Birmingham located between the Birmingham and Bushbury railway and the Birmingham and Derby railway for approximately 3.5km.

6.1.6 The Grand Union Canal is also located within this area, running adjacent and parallel to the River Rea for approximately 800m from north of Aston Church Road to where the river passes under the canal and flows east towards the River Tame at Dunton Trading Estate.

6.1.7 In the study area, the River Rea is crossed by Erskine Street, Duddeston Mill Road, Saltley Road, A47 Heartlands Parkway at two locations, Aston Church Road, the Stetchford and Aston railway, the Grand Union Canal and the B4137 Cuckoo Road.

6.1.8 In order to establish the existing flood risk posed by the River Rea to the land located along (and adjacent to) the route of the Proposed Scheme, reference has initially been made to the existing flood zone mapping available from the Environment Agency and shown on their website[21] and reproduced in WR01 within the Volume 5 Map Book.

6.1.9 The flood zone mapping indicates that a localised area of land along the Proposed Scheme is currently within Flood Zone 3. This indicates that it is at high risk from inundation from the River Rea (inundated during a flood event with a 1% AEP). The location within flood zone 3 is in the vicinity of B4114 Saltley Viaduct.

[20] Centre for Ecology and Hydrology (1999), *Flood Estimation Handbook (FEH)*

[21] http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=floodmap

6.1.10 There are also multiple locations in flood zone 2 (at risk of inundation during a 0.1% AEP flood event) These locations considered at medium risk include areas immediately adjacent to the river channel as well as:

- A4540Lawley Middleway;
- Landor Street;
- railway sidings land in the existing Freightliner Terminal;
- Duddeston Mill Road;
- industrial properties in Vauxhall between the River Rea and the Grand Union Canal ;
- B4114Saltley viaduct and;
- Saltley Business Park;
- Aston Church Road;
- Land surrounding the Nechell gasometers in the gas works off A47 Heartlands Parkway; and
- the majority of Gravelly Industrial Park.

6.1.11 All locations outside Flood Zone 2 and 3 are considered to be in Flood Zone 1 (only at risk during river flood events with a magnitude greater than the 0.1% AEP). As such flood zone 1 is at low risk.

6.1.12 To fully understand the existing risk posed by the River Rea and to be able to evaluate the impact of the Proposed Scheme on its hydraulic behaviour, an existing 1D/2D ISIS – TUFLOW river hydraulic model of the River Rea has been obtained from the Environment Agency.

6.1.13 This model was originally constructed by Royal Haskoning between August 2009 and July 2010 on behalf of the Environment Agency as part of a hazard mapping exercise of southern Birmingham. It was based on surveyed cross sections of the River Rea channel and the flood plain and included existing flood defences and significant hydraulic structures. The original model extended from the upstream extent of the River Rea as far as the Rea's confluence with the Tame. These survey data were gathered at various times during the development of these models. No new topographical river surveys have been carried out under this commission.

6.1.14 Following receipt of this model a significant amount of work was then undertaken to establish a robust model able to simulate the key storm simulations of interest to the project. This involved the following actions:

- resolving significant errors in the original model build;
- undertaking a preliminary review of the hydrological inputs to confirm the uncertainty related to the hydrological inputs were appropriate;
- trimming the model to focus on the project study area;
- updating the topographical data to reflect the most up to date LiDAR available. The grid size for this model was set at 6m and this has been left unchanged;
- incorporating structures missing from the model received; and
- develop and incorporate the existing bypass overflow channel located in the vicinity of Aston Church Road.

6.1.15 The details of the activities undertaken to produce a robust baseline river hydraulic model are documented in the River Rea modelling report found in Volume 5: Appendix WR-004-021.

6.1.16 The hydrological inputs into the hydraulic model are based on the original calculations undertaken on behalf of the Environment Agency. Details of this work can also be found in Volume 5: Appendix WR-004-021.

6.1.17 The results from the baseline model results are considered a more accurate representation when compared to the existing Environment Agency model due to the updates and refinements. At this stage of the design process for the Proposed Scheme, the River Rea baseline modelling outputs shown in this FRA and the accompanying drawings are only relevant to use in the context of the Proposed Scheme.

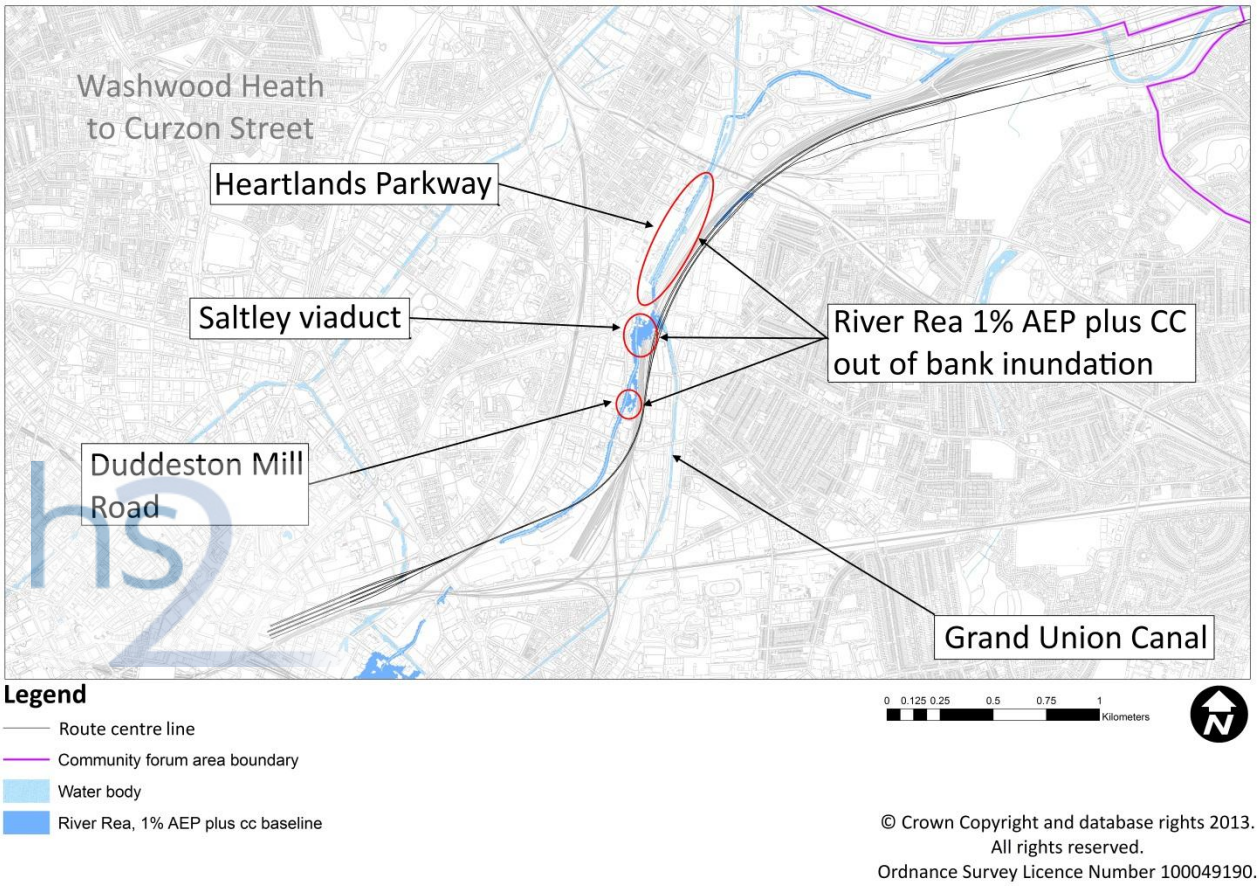
6.1.18 The baseline River Rea model has been used to determine water levels along the river channel and on the floodplain for the following flood AEP events in the pre-development state:

- 50%;
- 10%;
- 5%;
- 2%;
- 1%;
- 1% plus 20% CC; and
- 0.1%.

6.1.19 Although, the BCC SFRA does indicate occurrences of historic flooding along the River Rea, it does not identify locations in the vicinity of the Proposed Scheme as being affected. The areas impacted by river flooding along the River Rea are Edgbaston, Selly Oak and Northfield, all located at least 2kmfrom the Proposed Scheme.

6.1.20 The results from the baseline model for the 1% AEP plus CC have been mapped across the existing topography. These are shown in Figure 2 and in more detail on Map WR-05-158b-160 (Volume 5, Map Book Water resources).

Figure 2: Flood extent for the 1% AEP plus CC event along the River Rea from the baseline model



6.1.21 The mapping in Figure 2 indicates flooding at the following locations:

- a small area of inundation east of the main channel, approximately 200m downstream of Duddeston Mill Road;
- flood waters are indicated to inundate the Birmingham and Derby railway and flow into Grand Union Canal upstream of the culvert under A47 Heartlands Parkway, immediately downstream of B4114 Saltley viaduct; and
- inundation of the existing Grand Union Canal between Aston Church Road and B4114 Saltley Viaduct.

River Rea/Tame Confluence

6.1.22 It should be noted that in the River Rea baseline hydraulic model the influence of the River Tame is represented by using a downstream water level as a boundary condition. The boundary condition has been set based on possible water levels in the River Tame that could be experienced while the River Rea is in flood. However, a river hydraulic model of the River Tame also exists and this incorporates a section of the River Rea within it as a hydraulic element. As there are two potential sources for water levels in the vicinity of the River Rea/River Tame confluence the flood levels are based on the model which generates the higher level and the greater extent of flooding.

6.1.23 Joint probability analysis has not been undertaken.

River Rea Overflow Channel

6.1.24 An element of the River Rea system that is not reflected in the river hydraulic model received from the Environment Agency but which is affected by the Proposed Scheme is an existing bypass channel located in the vicinity of Aston Church Road. This feature is neither a main river nor an ordinary watercourse but occupies land owned by BCC. This feature is indicated in Figure 3.

6.1.25 By inspecting historic maps of the area it is noted that originally this feature was the main channel of the River Rea. The existing River Rea in this location was constructed as a mill race. As this area of Birmingham developed, the mill channel was adopted as the main channel of the river and the original channel became an overflow feature. The bypass overflow is in open channel until it passes under the existing railway line after which it enters a culverted section passing under the gas works before discharging back into the River Rea.

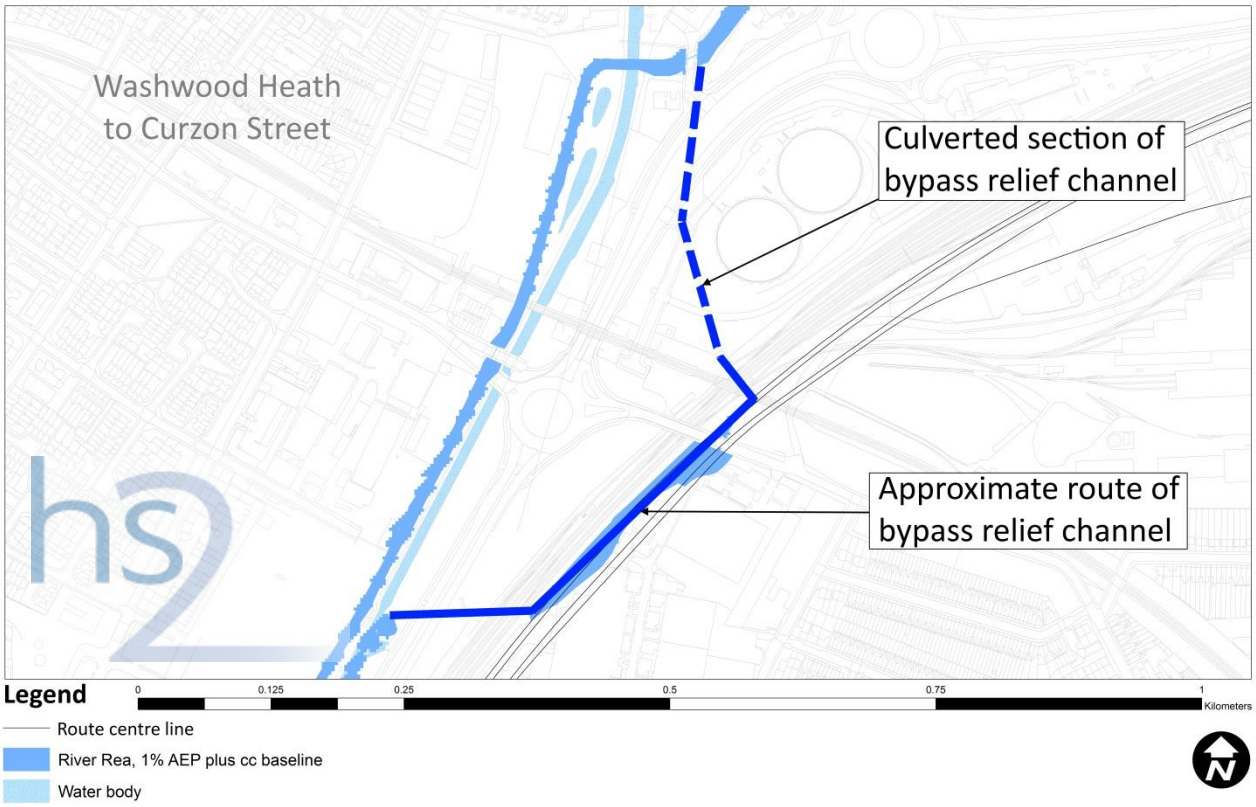
6.1.26 In order to establish the existing flood risk posed by this feature to the land located along and adjacent to the route of the Proposed Scheme, it was incorporated into the baseline river hydraulic model utilising LiDAR, historic drawings from 1928-9 provided by BCC and site inspection.

6.1.27 The overflow channel has been modelled utilising estimated data and historical drawings; this must be updated following a detailed survey and inspection.

6.1.28 From the baseline modelling results it appears that this channel does not accept flow from the River Rea for all but the most extreme flood events. However, asset location plan information indicates that this feature does accept surface water flows from the existing public surface water drainage system owned and operated by Severn Trent. Therefore water will be in the channel on a far greater frequency than represented by the model, although this will not impact the results of the river analysis.

6.1.29 The flooding extents produced by the baseline model take account of this feature and indicate this channel being used as a bypass within the 1% AEP plus CC event. This is shown in Figure 3.

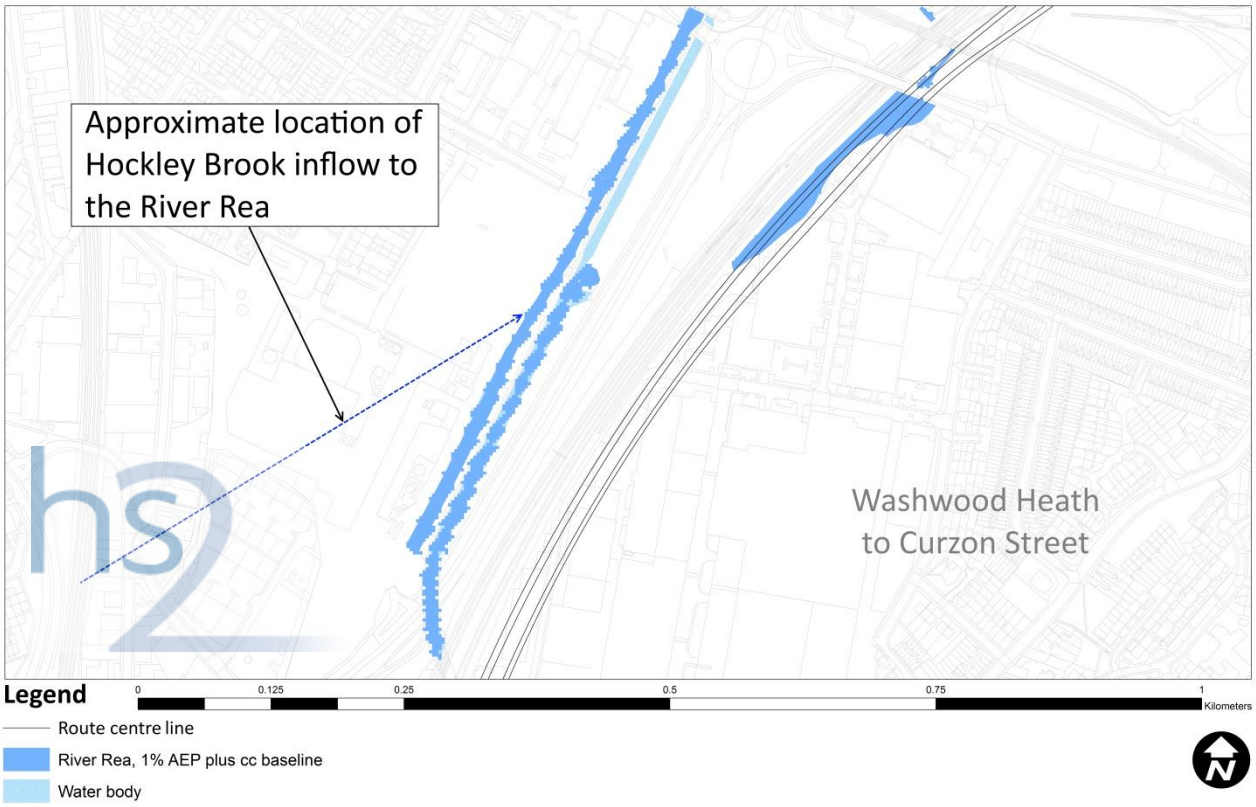
Figure 3: River Rea Overflow (relief) Channel operating during the 1% AEP plus CC



Hockley Brook

6.1.30 The Hockley Brook is a tributary of the River Tame, it is an ordinary watercourse and as such regulatory control lies with BCC. Along its course there is an overflow structure which directs a proportion of the water to the River Rea in a culvert through Nechells Green. The discharge point from the Hockley Brook Culvert into the Rea is located just upstream of weir inlet to the River Rea Overflow Channel. The Hockley Brook will not be affected by the Proposed Scheme and is not represented in the River Rea model hydraulically. However, it is represented as an inflow to the river system. The approximate location of this inflow is show in Figure 4.

Figure 4: Inflow of Hockley Brook to the River Rea



River Tame

6.1.31 The River Tame is the most significant watercourse in the West Midlands conurbation and drains a total catchment up to Alrewas of 1500km^2 (as taken from the FEH CD Rom) before discharging into the River Trent at Alrewas. The Tame catchment to Washwood Heath is approximately 350km^2. The majority of the catchment is heavily urbanised and the channel has been extensively modified for a large proportion of its length. It is a main river and as such is under regulatory control of Environment Agency (although riparian landowners do have a responsibilities to manage the river where it passes through their land and are restricted on what activities they can perform within or adjacent to the river without consent from the Environment Agency).

6.1.32 Within approximately 250m of the route, the River Tame flows along the north eastern boundary of the Star City commercial development. It is then joined by the River Rea and flows eastwards through more industrial and commercial areas such as Hurricane Park in a channel with natural banks and bed with some localised hard engineered reinforcement. The river then loops to the south and flows underneath the M6, the A47 Heartlands Parkway and the Derby to Birmingham Line.

6.1.33 In order to establish the existing flood risk posed by the River Tame to the land located along (and adjacent to) the route of the Proposed Scheme the same process has been followed as for the River Rea. As such, reference has been made to the existing flood zone mapping provided by the Environment Agency[22] and reproduced in WR01 within the Volume 5 Map Book.

6.1.34 This indicates that the following locations are in Flood Zone 3 and as such at high risk from inundation from the River Tame:

- the north-east extent of Gravelly Industrial Park;
- the east boundary of Hurricane Park;
- the east extent of Washwood Heath railway sidings;
- the central section of Bromford Lane/A47 roundabout; and
- sections of the Birmingham and Derby railway where the railway runs adjacent to the M6 and the River Tame is under the M6.

6.1.35 The areas at medium risk (Flood Zone 2) are indicated to include those listed below. These are all high vulnerability land uses and the impact of flooding would have a significant effect on both the land owners/operators in terms of the cost incurred and the water environment in terms of water quality implications:

- a much larger area of Washwood Heath railway sidings; and
- a much larger area of Gravelly Hill Industrial Park.

6.1.36 In order to fully understand the existing risk posed by the river and to be able to evaluate the impact of the Proposed Scheme on the hydraulic behaviour of the River Tame the following river hydraulic models have been obtained from the Environment Agency:

- 1D ISIS Strategic Flood Risk Management (SFRM) river hydraulic model; and
- 1D/2D ISIS - TUFLOW central visualisation river hydraulic model.

6.1.37 The 1D ISIS SFRM model is a detailed 1D model of the River Tame catchment.

6.1.38 Hydrological inputs are included based on detailed analysis of observed event data.

6.1.39 This model is comprised of an upper and lower Tame component. The upper Tame includes the Wolverhampton and Olbury Arms of the River Tame which combine upstream of Bescot and extends to Water Orton. The lower Tame extends to the confluence with the River Trent at Alrewas. Therefore, the component of relevance to the Proposed Scheme in CFA26 is the upper Tame.

6.1.40 The 1D/2D ISIS – TUFLOW central visualisation model is able to accurately model floodplain flow paths across floodplain due to its 2D domain and is also an unsteady state model.

[22] http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=floodmap

6.1.41 It is comprised of three component parts (upper, middle and lower). The naming of these models is independent of the naming of the SFRM model. The upper model includes the upstream extent of the River Tame catchment as far Newton near Great Barr. The middle Tame model covers Newton to Nechells and the lower Tame model, Nechells to Water Orton. Therefore, the Lower Tame component is of relevance to the Proposed Scheme.

6.1.42 Both of these models are based on surveyed cross sections of the River Tame channel and the floodplain and include existing flood defences and significant hydraulic structures. These survey data were gathered at various times during the development of these models. No new topographical river surveys have been carried out under this commission.

6.1.43 In order to create a robust river hydraulic model that can accurately simulate the behaviour of the River Tame during flood conditions, the hydrological inputs from the SFRM models have been input to the Central Visualisation model after differences in the model composition have been taken into account. In addition the grid size used to define the resolution of the topographical data used within the model has been reduced from 10m to 6m. This was undertaken to achieve consistency with the River Rea model.

6.1.44 The details of the activities undertaken to produce a robust 'baseline' river hydraulic model are documented in the River Tame modelling report found in Volume 5: Appendix WR-004-019.

6.1.45 The results from the baseline model results are considered a more accurate representation when compared to the existing Environment Agency model due to the updates and refinements. At this stage of the design process for the Proposed Scheme, the River Tame baseline modelling outputs shown in this FRA and the accompanying drawings are only relevant to use in the context of the Proposed Scheme.

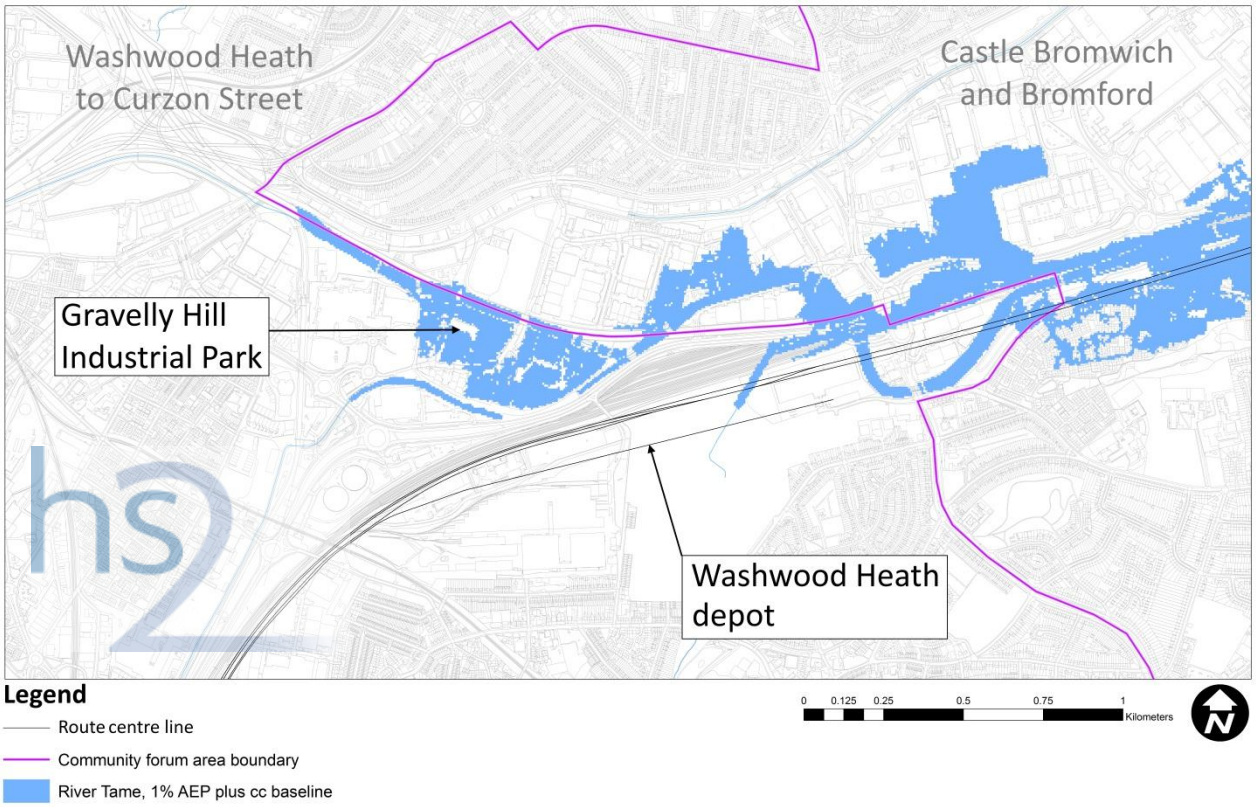
6.1.46 The baseline River Tame model has been used to determine water levels along the river channel and on the floodplain for the following flood events in the pre-development state:

- 50%;
- 10%;
- 5%;
- 2%;
- 1%;
- 1% + 20% CC; and
- 0.1% AEP.

6.1.47 The BCC SFRA does not indicate occurrences of historic flooding along the River Tame in the vicinity of the Proposed Scheme.

6.1.48 The results from the baseline model for the 1% AEP plus CC have been mapped across the existing topography. These are shown in Figure 5 and in more detail on the Map WR-05-158b to 160 (Volume 5, Map Book Water resources).

Figure 5: Bromford Area - Flood extent for the 1% AEP plus CC event along the River Tame from the baseline model.



6.1.49 The flood model extents shows inundation of the same areas as indicated by the Environment Agency flood zone mapping. However, there are some differences in flooding extent in some locations which are summarised below:

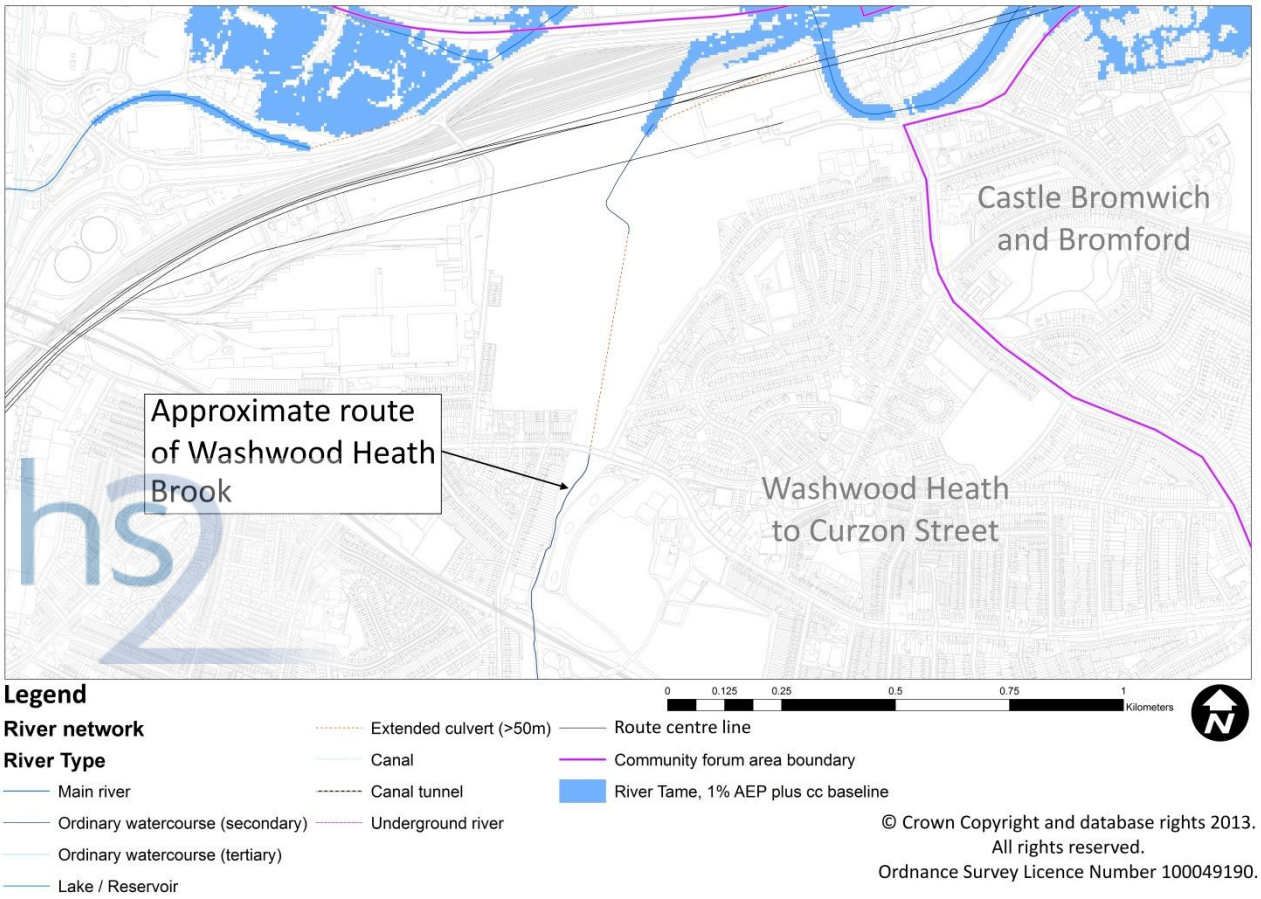
- increased inundation to Gravelly Industrial Park;
- increased inundation to industrial/commercial areas north of Hurricane Park;
- reduced inundation to the east extent of Washwood Heath railway sidings;
- inundation of Washwood Heath Brook by flood waters from the Tame;
- flooding of an existing oil storage depot west of the Fort Shopping Park
- reduced inundation to the west extent of residents south of the River Tame; and
- localised inundation of the Fort Parkway and the industrial/commercial areas, north of the A47 including the existing Jaguar plant.
- increased inundation of the existing Birmingham and Derby railway and north of the existing River Tame channel in Bromford; and
- reduced inundation in Castle Vale.

Washwood Heath Brook

6.1.50 The Washwood Heath Brook is predominately an urban drainage channel that is a tributary of the River Tame. The regulatory authority is BCC. It drains an urban area to the south of Washwood Heath. A short reach of this watercourse is located within the proposed Washwood Heath depot.

6.1.51 The baseline model of the River Tame includes the downstream extent of this feature as both a hydraulic feature as well as a point inflow. The modelling results indicate localised inundation of flood waters from the open section of the brook during the 1% AEP plus CC event.

Figure 6: Washwood Heath Brook, tributary to the River Tame.



6.2 Surface water and sewerage flood risk

6.2.1 This section is an examination of the existing flood risk posed by rainfall hitting the ground surface. This is often referred to as surface water. In this section it is examined in two ways (i) in terms of the risk posed in the event of failure or exceedance of existing drainage systems, and (ii) in terms of examining the pathways exploited by water flowing over the ground.

Drainage systems

6.2.2 The Proposed Scheme passes through the heavily urbanised central Birmingham, which is served by traditional urban drainage systems.

6.2.3 Surface water from these areas generally drain to a combined sewer system (meaning surface water and foul water are accepted into the same system) and is discharged to sewage treatment works.

6.2.4 At periods of high intensity rainfall when the capacity of sewers is exceeded, flows are sometimes discharged through combined sewer overflows (CSOs) to local watercourses such as the Tame, Rea and their tributaries. CSO's were designed to offer capacity improvements to the system and in some instances they are able to provide storage and so regulate the rate of discharge. However, in some instances the systems are unable to provide any storage and so the flow from the CSO to the watercourse is unattenuated.

6.2.5 There are about 30 drainage area zones covering the whole of the Birmingham area. These drain down various trunk sewers to the Minworth waste water treatment works on the north-eastern side of the city.

6.2.6 The majority of the system is the responsibility of Severn Trent Water. Although, within this overall system there are also separate surface water sewers. These tend to be BCC highway drains or privately owned. These take the run-off directly to the local brooks, watercourses or the Severn Trent Water sewerage system.

Route wide within CFA26

6.2.7 The existing sewer networks within the catchments affected by the Proposed Scheme are described below.

6.2.8 The trunk sewers serving the catchments in the vicinity of the Proposed Scheme flow north to south along a route parallel to the Grand Union Canal and the River Rea, between Curzon Street and Nechells.

6.2.9 From Nechells to Minworth the main trunk sewer flows eastwards parallel to the Birmingham and Fazeley Canal.

6.2.10 East of Washwood Heath, large urban areas in the River Tame valley lie below the level of the receiving trunk sewer. Therefore discharges from foul and combined sewer networks are pumped into this trunk main.

6.2.11 Districts on the south of the River Tame on higher ground in Castle Bromwich and Hodgehill are served by foul and combined sewer systems which also outfall to this trunk sewer via pumping stations and siphons which traverse the river valley. This includes a combined sewer comprised of four 1200mm wide diameter sewers. These pass under the River Tame and its floodplain to the west of the proposed Bromford tunnel west portal.

6.2.12 The flood risk posed by the existing sewerage systems located along the Proposed Scheme has been qualitatively assessed. Information from BCC's Level 1 SFRA and the PFRA indicates where historic sewerage flooding has occurred. No historic flooding from sewers is shown along the Proposed Scheme in the BCC SFRA plans found in Annex A.

Location of the proposed Curzon Street station

6.2.13 Existing buildings and hard standings in the area are served by foul and combined public sewers. These are aligned primarily within the diagonally running public highways and the majority fall in a south-easterly direction, passing under the Rugby to Birmingham/ Birmingham and Derby railway corridor before flowing northwards within the main trunk sewer which follows the River Rea and the Grand Union Canal.

6.2.14 Based on the sewer network data from Severn Trent Water most of the major sewers within the proposed Curzon Street station location are brickwork or concrete pipes with diameters between 350mm to 1500mm.

6.2.15 There has not been any reported historic flooding caused by existing sewers in this location reported in the BCC's SFRA or PFRA.

Location of the proposed Washwood Heath depot

6.2.16 Washwood Heath is served by separate foul and surface water sewers, aligned primarily within the public highways.

6.2.17 Surface water from Warren Road, Leigh Road and Common Lane drains through the development area. The STW sewers change from buried pipe to open channel and finally buried culvert. The downstream culverted section conveys flows beneath the Birmingham and Derby railway and the A47, and outfalls into the River Rea a short distance upstream of its confluence with the River Tame. This section of the sewer is not indicated on STW asset location plans and is likely to be the responsibility of BCC.

6.2.18 A public foul water sewer crosses the development area beneath the former Alstom site and existing Cemex site at the western end of the proposed depot. The sewer discharges into a combined system located immediately north of the Birmingham and Derby railway. From here flows are conveyed north and then east to Minworth sewage treatment works.

6.2.19 At present there is no recorded information about the privately owned drainage system within the development area. The area has an established industrial tradition with a mix of working and abandoned facilities. Therefore an extensive network of privately operated sewers is anticipated. These sewers are assumed to emulate the operation of the known systems and drain to the north.

6.2.20 There has not been any reported historic flooding caused by existing sewers in this location reported in the BCC's SFRA or PFRA.

Surface water flow flood risk

6.2.21 The assessment of the existing flood risk posed by existing surface water flow routes has been based on the following:

- an investigation of existing topography using contours generated from LiDAR survey data;
- examining the Environment Agency's surface water flood mapping; and
- documenting any reported instances of flooding from the BCC's SFRA.

Route wide within CFA26

6.2.22 The Proposed Scheme follows the valley of the River Rea and the River Tame. Consequently local surface water routes are towards the Proposed Scheme.

6.2.23 This means that between Curzon Street and Nechells, where the River Rea valley is followed, the direction of flow is from the east and west and from Nechells to Water Orton, where the River Tame valley is followed, surface water flow is from the north and south. The general direction of surface water flow is shown in Annex B.

6.2.24 However, the high levels of urbanisation within Birmingham including the extensive road, rail and canal networks mean that the opportunity for water to flow across the valleys is far more limited than suggested on these plans as these do not account for the cities infrastructure.

6.2.25 The Environment Agency's surface water flood mapping has also been examined and is shown in Map WR-01-26 (Volume 5 Map Book Water resources). These have been compiled by the Environment Agency using a simple ground model to indicate where surface water is expected to flow or pond during the 0.5% AEP rainfall event. The mapping provides an indication of flooding greater than 0.1m depth and flooding greater than 0.3m deep. This data does have limitations but illustrates where more detailed study may be required as the design develops.

6.2.26 On the whole the data set does pick up the significant features that will be expected to be inundated by significant depths of water during rainfall events. These include watercourses and canals as well as the features of interest in this assessment such as low spots in topography. However, the low resolution of the mapping and the fact that existing surface water sewerage infrastructure is not considered in the analysis means that a great number of 'low spots' are identified as potential 'at risk locations'. Therefore, a large number of locations across the Package are identified with a particularly high frequency of surface water flooding in Bromford and Castle Vale.

6.2.27 Despite this, the data set has been used to identify the following locations along or in close proximity of the route of the Proposed Scheme where surface water flow may be a flood risk consideration:

- Lawley Middleway where it passes under the existing railway bridge;
- Duddeston Mill Road under the existing rail bridge;
- an industrial area in the Vauxhall area of Birmingham south of B4114 Saltley Viaduct; and
- Saltley Business Park.

6.2.28 An instance of historic flooding in the Bromford area has been attributed to surface water flow. This is identified in BCC's SFRA. This is not indicated to be in close proximity to the route.

Location of the Proposed Curzon Street station

6.2.29 In the location of the proposed Curzon Street station, the major surface water flow routes appear to be across along the diagonally orientated roads (Banbury Road, Fazeley Street and Bordeslely Street).

6.2.30 Water is able to leave the area through the existing railway bridge opening and will eventually discharge into the Digbeth Canal, if not intercepted by the existing surface water drainage system. Water cannot discharge straight into the River Rea as this is culverted.

6.2.31 It should be noted that water will be able to enter the proposed Curzon Street station area from Moor Street Queensway, which is elevated above the proposed station site. This will be mitigated by having, for example, retaining structures and linear drains in affected areas.

6.2.32 The Environment Agency's surface water flood mapping indicates areas of accumulation of surface water at the northern end of New Bartholomew Street, along Banbury Road in the vicinity of the existing rail crossing and along Curzon Street. The maps also identify the Digbeth Branch Canal as an area where water will accumulate.

Location of the proposed Washwood Heath depot

6.2.33 The location of the proposed Washwood Heath depot is a large relatively flat expanse. Significant surface water flows paths have not been identified across the site from the contour plan information. However, potential surface water accumulations have been identified on the Environment Agency's surface water flood mapping. This data source identifies the Washwood Heath Brook, the open drainage feature along Common Road as well as numerous hollows and depressions across the site.

6.3 Groundwater

6.3.1 Groundwater flood risk within the Washwood Heath to Curzon Street area has been qualitatively and quantitatively assessed based on hazard identification and evaluation using the conceptual understanding of the ground conditions along the route as informed by geotechnical desk studies and by initial groundwater modelling. The assessment of current groundwater flood risk is based on the presence or otherwise of an aquifer and the relative depth to groundwater level, as well as historical information on the occurrence of groundwater flooding incidents.

Baseline description

6.3.2 The following sections present details of the ground conditions along the route of the Proposed Scheme within the area and a literature review of historical groundwater flooding incidents from the BCC's SFRA and Environment Agency reporting.

Geology

6.3.3 The solid and superficial geology of the route corridor is presented below.

Solid Geology

6.3.4 The geological structure of the eastern section of the Proposed Scheme within CFA26 comprises Triassic deposits (Mercia Mudstone Group), forming part of the Knowle Basin, overlain by glacial and alluvial superficial deposits.

6.3.5 At the A4040 Lawley Middleway, the proposed route crosses the line of the Birmingham Fault which lies between the surface features of Cardigan Street and the Lawley Middleway/Curzon Street junction, and trends south-west to north-east. This fault exposes the Triassic Sherwood Sandstone Group, Bromsgrove Sandstone Formation to the west of the fault. Consequently this stratum is present beneath the footprint of the proposed new Curzon Street station.

6.3.6 The Arden Sandstone Formation occurs within the Mercia Mudstone as a thin discontinuous horizon of siltstone and sandstone. An outcrop of the Arden Sandstone is mapped outside the study area to the east,

Superficial geology

6.3.7 The superficial deposits overlying the solid geology includes the following strata:

- Alluvial deposits;
- River Terrace deposits;
- Glacial deposits; and
- Made ground.

6.3.8 The River Rea Alluvial Deposits, laid down by the Rivers Rea and the Tame since the end of the last (Devensian) glacial period, generally comprise clayey silts, sand and gravel and can be up to 5m thick, typically 3 – 4m. In many places the alluvial material has been disturbed by the construction of mills, flood defences, and urban development, and merges into an extensive spread of made ground reflecting human activities.

6.3.9 River Terrace Deposits are also present along the valley bottom of the River Rea, but are poorly defined, and overprinted by urban development. However, along the valley bottom of the River Tame, there are a well-developed series of River Terrace Deposits.

6.3.10 The younger and more extensive deposit (the First Terrace) as formed during the last glacial period when the Devensian Ice Sheet encroached into the catchment of the River Tame in the Walsall area and is comprised of a sand and gravel layer that is generally 4–5m thick. This was originally 1–3m above the present day alluvial flood plain, but this relationship is largely obscured by urban development and filling across the valley bottom. The terrace deposits have been dug for sand and gravel at the junction of the Rea and Tame valleys just north of the A47 Heartlands Parkway over the River Tame.

6.3.11 The older Second Terrace (Hams Hall Terrace) occurs as a semi-continuous feature along the lower part of the valley side, particularly on the north side. It generally occurs about 7m to 9m above the present day floodplain, but the elevation is variable, and there may be more than one age of material. It comprises a clayey sand and gravel, generally 2m to 4m thick, which is extensively cryoturbated in places.

6.3.12 The superficial glacial deposits form a discontinuous covering to the Triassic deposits across the upper parts of the River Rea and River Tame valley sides. These deposits probably reflect several phases of glaciation between about 400,000 and 200,000 years ago. Due to erosion by the River Rea and River Tame after the last glacial phase, the cover of glacial material is now discontinuous. They also occur within linear hollows eroded into the Triassic strata, by subglacial melt water during a previous glacial period.

6.3.13 A notable feature is a buried glacial channel up to 30m deep and infilled with glacial deposits at Aston Church Road and Network Park. This channel was originally associated with a pre-glacial course of the River Tame, and is referenced as the extent of an infilled glacial channel.

6.3.14 Most of the glacial deposits present are sands and gravels formed during the decay of the glacial phases. However within the subglacial channel, a more diverse sequence of glaciolacustrine silts and fluvio-glacial sands and gravel occur, and within this sequence interglacial deposits are present in places, indicative of possibly more than one glacial phase.

6.3.15 Significant spreads of made ground affect CFA26 relating to past human activities. Much of this made ground has been placed across the valley bottoms of the Rivers Tame and Rea to provide development platforms above flood levels for industrial land use, and as embankments for main line railways and extensive railway sidings. Some of this made ground is a consequence of the long and intensive industrial land use of the area.

Hydrogeology

6.3.16 The strata have been classified using the Environment Agency aquifer classification framework which is consistent with EU Water Framework Directive (2000)[23]. The aquifer designations for each stratum are summarised in Table 3.

Table 3: Aquifer designations for geological units in Washwood Heath to Curzon Street area

Geological unit	**Aquifer designation**
Alluvium	Secondary A
River Terrace Deposits	Secondary A
Glaciofluvial Deposits	Secondary A
Mercia Mudstone	Secondary B
Sherwood Sandstone	Principal

6.3.17 The aquifer classification is as follows:

- secondary A aquifers are considered to consist of variable permeability layers capable of supporting water supplies at a local scale;
- secondary B aquifers are predominantly of lower permeability and may locally store groundwater due to localised features such as thin fissures, thin permeable horizons and

[23] *Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy*, European Council

weathering; and

- principal aquifers are highly inter-granular and/or fractured and the permeability is such that they are able to support water supply and river base flow at a strategic scale.

6.3.18 No Groundwater Source Protection Zones (SPZ) are located along or within 250m of the proposed route the nearest SPZ being located approximately 330m west of the far western extent of the proposed route as shown on drawing WR-02-26 Groundwater Baseline.

Historical occurrence of groundwater flooding

6.3.19 Information on groundwater flood risk was obtained from BCC's Level 1 SFRA (2012), CIRIA report into groundwater levels in Birmingham (1993)[24] and the Environment Agency 2006 report "Making Space for Groundwater - Non-Chalk aquifers"[25] which included a national survey of known groundwater flooding issues.

6.3.20 The main area of groundwater flood risk identified in these reports is the area west of the Birmingham Fault within the Sherwood Sandstone Group (Bromsgrove Formation) the approach to Curzon Street.

6.3.21 The Triassic Sandstones that underlie much of the city of Birmingham are water bearing (classified Principal Aquifer) and were used for well over a century as a major source of supply for local industry and commerce, and originally also for local public water supply. Between about 1860 and 1930 many wells and boreholes were sunk to meet the needs of industrial development and urbanisation. Abstraction rates exceeded recharge, as a direct consequence groundwater levels in the sandstone aquifer fell. Pumping reached a peak in the late 1940s and early 1950s but water levels continued to decline.

6.3.22 During the last 40 years there has been an appreciable reduction in the amount of pumping in the area, reflecting the declining fortunes and changing practice of many of the industrial consumers. Licensed abstractions within the Birmingham Groundwater Unit have fallen in total to less than a fifth of the peak, from an estimated maximum of over 75Ml/d (megalitres per day) during the 1940s, to less than 15Ml/d in 1993. The excess of natural recharge and leakage over abstraction from the aquifer has led to a rapid rise in groundwater levels.

6.3.23 Eventually the groundwater surface will return to pre-industrial levels, subject to the effects of changes in surface land use, drainage and continued abstractions. In 1993 CIRIA produced a review of the changing groundwater levels within the Birmingham Aquifer. This indicated that rising groundwater levels in the main Sherwood Sandstone units could overspill into superficial groundwater units over a wider area. This is particularly the case along the Birmingham Fault where groundwater appears to have spilt into the superficial aquifers overlying the Mercia Mudstones, in the early 1990s, elevating local groundwater levels.

[24] CIRIA (1993), *Rising groundwater levels in Birmingham and the engineering implications*

[25] Environment Agency (2006), *Making Space for Groundwater - Non-Chalk aquifers*

Current groundwater flood risk

6.3.24 The nature of groundwater flood risk is distinct either side of the Birmingham Fault (in the vicinity of A4540 Lawley Middleway) where ground and groundwater conditions are very different.

6.3.25 To the east of the Birmingham Fault the route is underlain by generally impermeable (except for weathered top zone and some sand bands) Mercia Mudstone with overlying predominantly free draining sand and gravel superficial deposits such as the River Terrace deposits and glaciofluvial deposits which are designated Secondary A aquifers and will expect relatively shallow, less than5m depths groundwater along the valleys.

6.3.26 To the west of the Birmingham Fault the Bromsgrove Sandstone Formation (Sherwood Sandstone Group) is classified as a Principal aquifer. This unit has experienced rising groundwater levels during the last 30 years with warnings of groundwater flooding in parts of the city. It is understood groundwater levels have now largely stabilised within the city centre area, but can be expected at shallow depth. Shallow and mobile groundwater may be expected throughout the route. At the Birmingham City University site near Curzon Street, groundwater was monitored from 2 to 5.5m deep within the glaciofluvial deposits and weathered Bromsgrove Sandstone.

6.3.27 A notable feature within the area is a buried glacial channel up to 30m deep in filled with heterogeneous glacial deposits which is located approximately between Aston Church Road and the Duddeston Viaduct. Overspill of groundwater from the Sherwood Sandstone across the Birmingham Fault into the superficial deposits of the Tame Valley has been reported.

6.4 Artificial sources /infrastructure failure

6.4.1 Artificial sources of flood risk describe a mechanism whereby flooding will be the cause of failure of infrastructure in place to impound (reservoir), retain (dam) or convey water (water pipeline).

6.4.2 In the Washwood Heath to Curzon Street area, flooding is a possibility from the failure of the following infrastructure:

- the canal system;
- sewerage systems (detailed in Section 6.2);
- water supply pipe networks; and
- reservoir failure.

The Canal system

6.4.3 The key features related to Birmingham's extensive canal system in the vicinity of the Proposed Scheme are listed below based on inspection of Ordnance Survey mapping and BCC maps. The locations of these features are indicated in the BCC SFRA plans found in Annex B:

- Worcestershire and Birmingham Canal;
- Birmingham Canal;

- Gas Street Basin;
- Digbeth Branch Canal;
- Grand Union Canal (also named the Birmingham and Warwick Junction Canal on the Canal and Rivers Trust website);
- Birmingham and Fazley Canal; and
- Tame Valley Canal.

6.4.4 From inspection of mapping sources and aerial photographs it is evident that on the whole the canal system within Birmingham sits at a low level compared to surrounding land and therefore does not pose a flood risk to adjacent land due to a breach.

6.4.5 Ordnance Survey mapping, LiDAR data and aerial photographs have also been used to assess the impact of canal overtopping to the land along the route of the Proposed Scheme in its existing state. This is discussed for each canal feature in the following sections

Worcestershire and Birmingham Canal

6.4.6 This canal enters the Birmingham conurbation for the south west and enters Gas Street Basin. Localised overtopping of this canal if it did occur, which is unlikely, will not impact any land, in its existing state along the Proposed Scheme. There are two aqueducts along this canal at Bourneville and Selly Oak. Breaches of these will cause local flooding but will not impact on the Proposed Scheme which is approximately 7km downstream.

Birmingham Canal

6.4.7 This canal enters Gas Street Basin from the north-west. Localised overtopping of this canal if it did occur, which is unlikely, will not impact any land, in its existing state along the Proposed Scheme.

Gas Street Basin

6.4.8 This is the intersection between the Worcestershire and Birmingham and the Birmingham Canals. It is located approximately 1km from the southern extent of the Proposed Scheme. Localised overtopping of this canal, if it did occur which is unlikely will not impact any land, in its existing state along the Proposed Scheme.

Digbeth Branch Canal

6.4.9 The north-eastern end of the proposed station at Curzon Street passes over the Digbeth Branch Canal. The Digbeth Branch Canal connects the Grand Union Canal to the Birmingham and Canal. An uncontrolled breach of the canal in this location is not physically possible due to the canals relative elevation compared to the surrounding topography.

Grand Union Canal

6.4.10 The Grand Union Canal itself ultimately connects London to Birmingham and beyond. It is fed by the Grand Union Canal branching from the Digbeth Branch Canal and then continues northwards, through Birmingham, until it reaches the Birmingham and Fazeley Canal, in the vicinity of Gravelly Hill. Between Duddeston Road and Aston Church Road it is located within 200m of the Proposed Scheme. The Proposed Scheme will cross the Grand Union Canal in the vicinity of B4114 Saltley Viaduct. Localised overtopping of this canal is extremely unlikely based on the relative levels of the canal and the surrounding topography. However, if it did occur the most likely receptors will be the areas of the Saltley Business Park and Network Park Industrial Estate in closest proximity to the canal.

Birmingham and Fazeley Canal

6.4.11 The Birmingham and Fazeley Canal runs north-eastwards through Birmingham from Gas Street Basin as far as Junction 6 of the M6 at Gravelly Hill where it then bears eastwards. Between Gas Street Basin and Gravelly Hill the canal runs on an alignment that is approximately 1.5km to the west of the Proposed Scheme. From Gravelly Hill eastwards it is located a minimum of 500m to the north of the Proposed Scheme. .In the unlikely event that overtopping of the canal did occur, it will not impact on land in its current state adjacent to the Proposed Scheme.

Tame Valley Canal

6.4.12 The Tame Valley Canal runs between the Birmingham and Fazeley/Grand Union Canal at Gravelly Hill to the Walsall Canal near Tipton. Localised overtopping of this canal if it did occur, which is unlikely, will not impact any land, in its existing state along the Proposed Scheme.

Water supply network

6.4.13 Water mains and water distribution infrastructure are a potential source of flood risk in the event of a failure. This section identifies significant water mains within the network and their position relative to the Proposed Scheme for the baseline condition.

6.4.14 Significance of a water main is based on diameter and pressure. It is assumed that the majority of small diameter pipes within the network are of low risk as the rate at which water escapes will be low. Where the risk is not considered to be low the utility is presented in Figure 7, Figure 8 and Figure 9.

Figure 7: Birmingham water mains

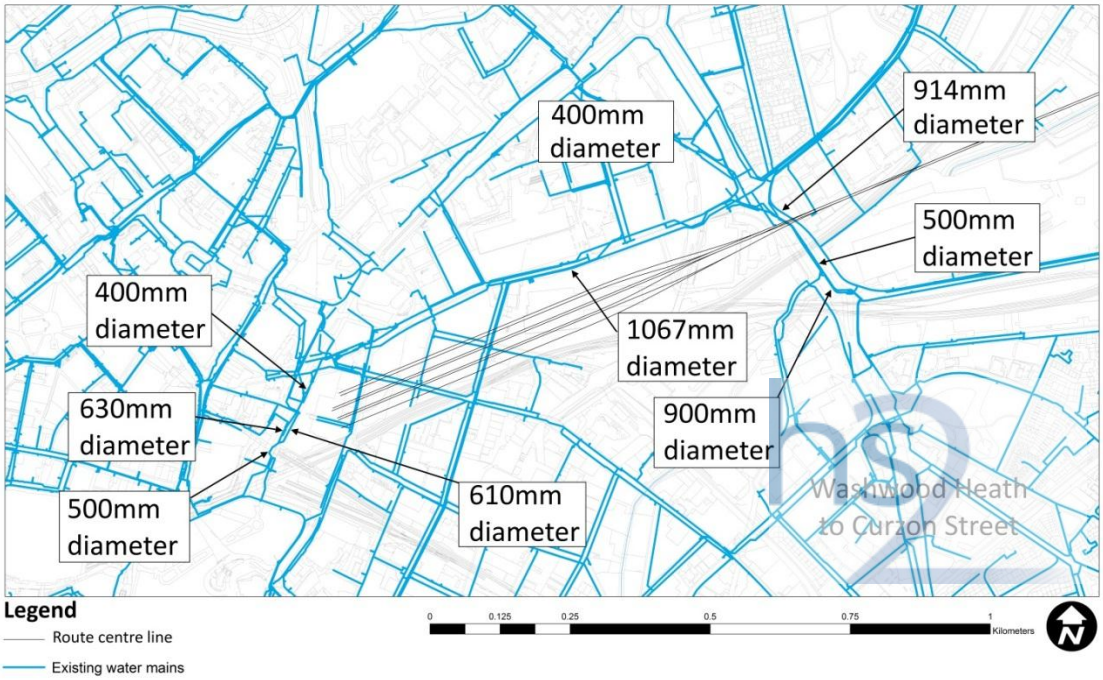


Figure 8: Saltely water mains

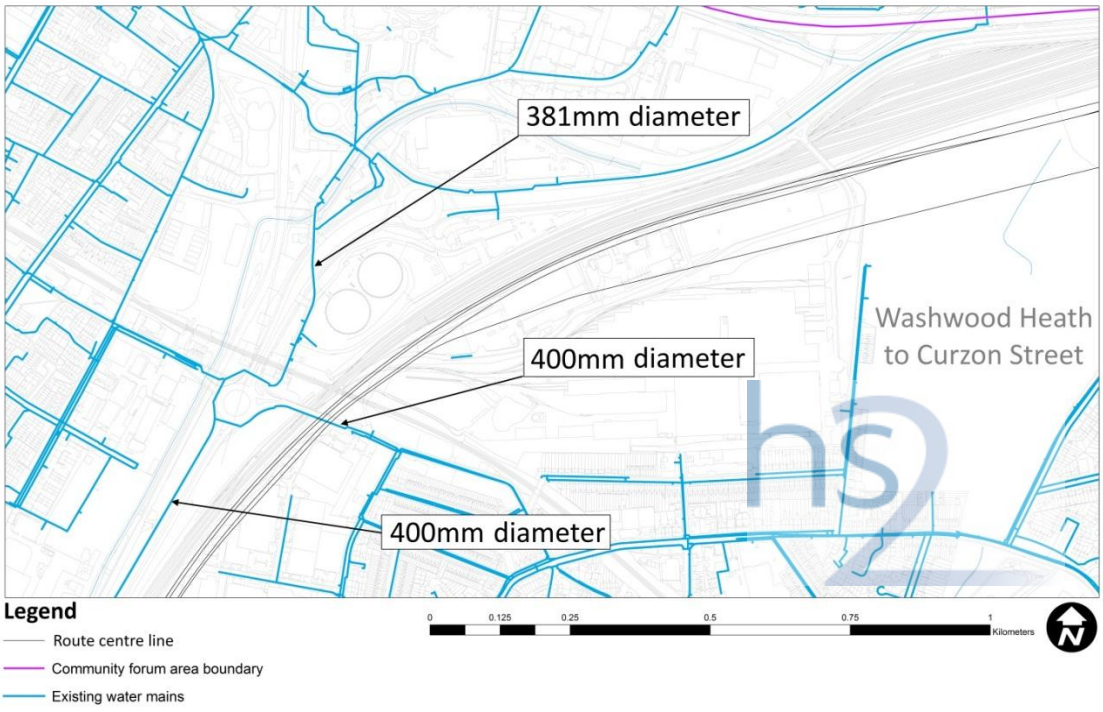
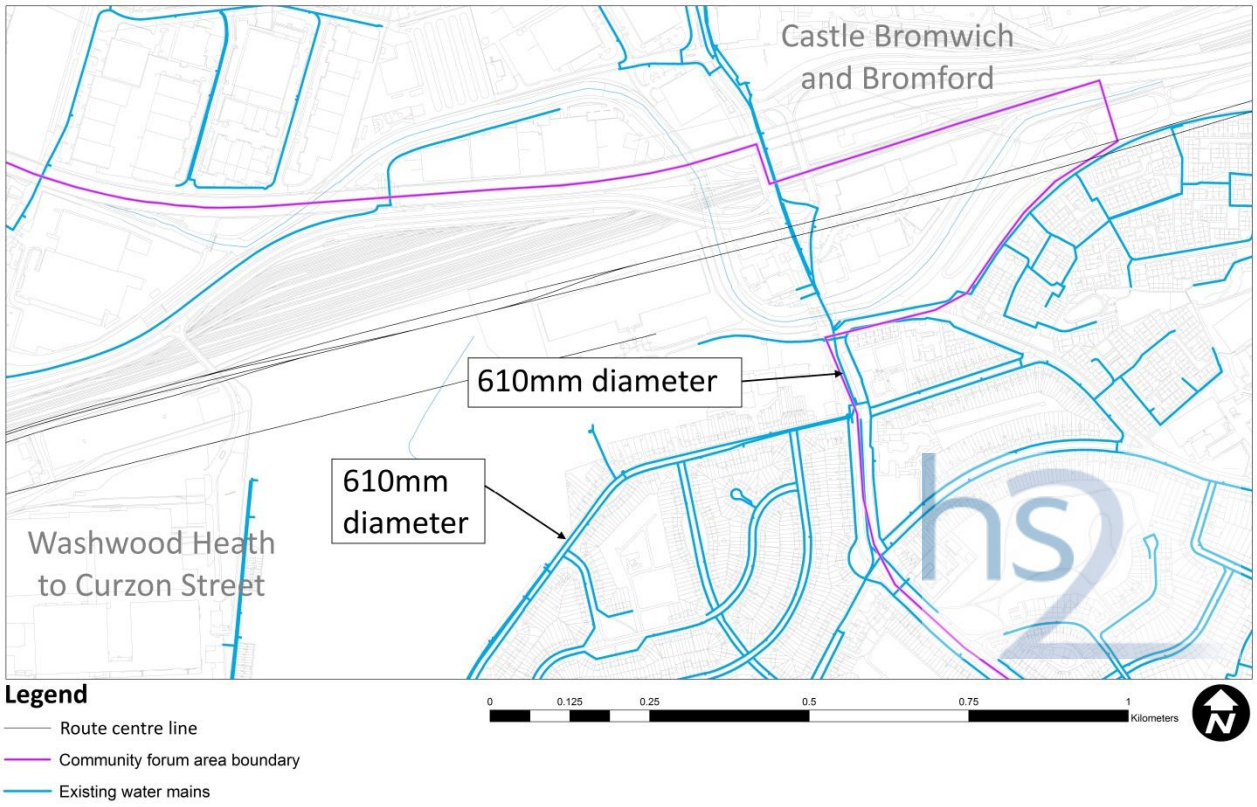


Figure 9: Washwood Heath water mains



6.4.15 An assessment of how existing water supply infrastructure interacts with the Proposed Scheme has been undertaken.

Reservoir failure

6.4.16 The probability of flooding occurring from the failure of a reservoir or large water body created by impoundment of water, by a dam or other retaining structure is extremely low. The Environment Agency's website reports that there has been no loss of life due to reservoir failure in the UK since 1925. All large water bodies across the UK have to be maintained and monitored to a very high standard under the Reservoir Act 1975[26]. This requires regular inspection of any water body designated a reservoir by a nominated engineer. However if a reservoir does fail the impact is likely to be severe and far reaching. It is a requirement of NPPF and The Flood and Water Management Act 2010[27] to evaluate the implications of reservoir failure on all proposed development even if the likelihood is very low. The Flood and Water Management Act 2010 proposes to change the capacity threshold at which reservoirs are regulated from 25,000m^3 to 10,000m^3. Secondary legislation which has yet to be enacted is required to enforce this change.

[26] *Reservoir Safety Act* (1975), London, Her Majesty's Stationary Office

[27] *The Flood and Water Management Act* (2010), London, Her Majesty's Stationary Office

6.4.17 To that end the Environment Agency's reservoir failure mapping for the Birmingham area has been compared to the Proposed Scheme. It should be noted that this only accounts for large reservoirs (those in excess of 25,000m^3).

6.4.18 This indicates that in the event of a catastrophic failure of the reservoirs in the Rea and Tame catchment the flood waters will flow down the rivers channels and extend out across the flood plain of both river systems.

6.4.19 There are three water bodies identified on the Environment Agency Reservoir Inundation Maps that have the potential of inundating the Rea valley in the vicinity of the Proposed Scheme. The location of these water bodies is indicated in the BCC SFRA plans found in Annex A listed below:

- Edgbaston Pool adjacent to Edgbaston Golf Course which feeds the River Rea via the Chad Brook and the Bourn Brook and is located 4km south of the southernmost point of the Proposed Scheme;
- Bartley Reservoir – feeds the Bourn Brook via Stonehouse Brook and is located approximately 8km upstream of the Proposed Scheme; and
- Frankley Reservoir – feeds the Rea via Merritts and Griffin Brook and is located approximately 8km upstream of the Proposed Scheme.

6.4.20 There are a number of water bodies identified on the Environment Agency Reservoir Inundation maps that have the potential of inundating the Tame valley in the vicinity of the Proposed Scheme. These are also shown in Annex A and listed below:

- a covered reservoir located in Stockland Green that is indicted to have a 3.5km overland route to the River Tame in Bromford;
- Aston Reservoir located within the Tame floodplain at M6 Gravelly Hill interchange. It is located 1.5km upstream of the Proposed Scheme;
- Great Barr Reservoir and Perry Reservoir are indicated along a watercourse that flows through Perry Park, a tributary of the Tame. This watercourse enters the Tame at Witton, approximately 5.5km from the Proposed Scheme;
- Forge Mill Lake in Sandwell Nature Reserve located 19km north of the Proposed Scheme, along the main River Tame channel to the Proposed Scheme; and
- a covered reservoir located at Kingstanding drains into a tributary of the River Tame. Along this watercourse there are two other large water bodies; Witton Lakes and Brookvale Park boating Lake. A significant area of elevated land is located at the downstream of the boating lake. The flooding extent indicates that flood waters from a reservoir breach will be attenuated preventing waters reaching the Tame in an uncontrolled manner.

6.4.21 Rotten Park (Edgbaston Reservoir) feeds the Birmingham Canal. This is located approximately 4km from where Proposed Scheme will be located (see Annex A).

6.4.22 In most areas the extent of inundation will be approximately equivalent to the 0.1% AEP flood event. However, the Environment Agency data provided does not indicate flood depths, flow velocities or the time taken for onset of flooding after a breach takes place.

6.4.23 It should be noted there are other water bodies identified on BCC's water feature maps located within the Tame and Rea catchment. Due to their size they will have not been subject to the reservoir inundation analysis. These include Wychall Pond and Lifford Reservoir both located along the Rea (approximately 5km upstream of the Proposed Scheme) and a boating lake located along Washwood Heath Brook.

6.5 Summary of baseline flood risk

Table 4: Summary of baseline flood risk for all sources of flooding in CFA26

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Rivers	River Tame	High FZ3b	Bromford tunnel west portal	Flood protection walls implemented to safeguard portal up to the 0.1% AEP water level
		Low Flood Zone 1	Washwood Heath Depot	Flood protection walls implemented to safeguard depot from inundation in excess of the 0.1% AEP flood event.
		High	Network Rail	Culverts under Network Rail sized to match existing and maintain current flood conditions.
	Washwood Heath Brook	High Flood Zone 3	Bromford tunnel west portal	Washwood Heath Brook being realigned around depot and away from portal. Realigned channel designed to convey flood waters away from portal and depot.
		Low Flood Zone 1	Washwood Heath depot	

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
	River Rea	Low to High Flood Zone 1 - 3	Curzon Street viaducts 1-3 and Saltley retained fill	The route runs in close proximity to the River Rea and so crosses all flood zones. However, the level of the track has been designed based on modelled flood levels plus the minimum freeboard requirements as such The Proposed Scheme is at low risk from the River Rea
	River Rea Overflow Channel	High Flood Zone 3	Saltley retained fill	Route located in the position of the existing River Rea Overflow Channel. Route of the channel has been realigned to the west side of the Birmingham and Derby Line and the level of the Proposed Scheme has been designed based on modelled flood levels plus the minimum freeboard requirements as such The Proposed Scheme is at low risk from the River Rea Overflow Channel.
Artificial sources	Water bodies contributing to the River Rea including Reservoirs at Frankley, Bartley and Edgebaston Pool Water bodies contributing to the River Tame including reservoirs at Perry Park, Aston Reservoir and Stockland Green	Low - Within inundation mapping / pathway exists	Bromford tunnel west portal	Flood protection walls will be designed to the 0.1% AEP flood level plus appropriate freeboard
			Proposed Scheme (embanked and viaducts)	Proposed Scheme set at above 0.1% AEP flood level plus appropriate freeboard
			Washwood Heath depot	Depot protected by flood walls implemented to safeguard west portal up to the 0.1% AEP water level.
Surface water	Proposed Scheme track drainage	Low	River Tame	Additional run-off from Proposed Scheme track drainage will be attenuated to pre-development greenfield/brownfield run-off rates within balancing ponds prior to discharge to watercourse.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Surface water	Bromford tunnel west portal pumping station	Low	River Tame	Outflow from pumping station will be attenuated to pre-development run-off rates within balancing ponds prior to discharge to the River Tame. Pump station outfall ditch and pond provided to reduce flow surges from pumps.
Surface water	Bromford Road,A4040	High	Bromford Road & A4040 road drainage network and River Tame (AEP >1.3 %)	Surface water runoff increased from proposed scheme to be attenuated prior to discharge into River Tame. Part of increased runoff from proposed scheme will be re-used in rainwater harvesting system.
Surface water	Washwood Heath depot	Low	River Tame	Additional run-off from the depot drainage will be attenuated to pre-development greenfield/brownfield run-off rates within balancing ponds prior to discharge to Washwood Heath Brook diversion.
Combined Sewer -Severn Trent Water	Proposed scheme	Low and medium risk	Proposed scheme	Existing sewer diverted to avoid conflict with Proposed Scheme
Surface water	Bromford Road,A4040	High	Bromford Road & A4040 road drainage network and River Tame (AEP >1.3 %)	Surface water runoff increased from proposed scheme to be attenuated prior to discharge into River Tame. Part of increased runoff from proposed scheme will be re-used in rainwater harvesting system.
Surface water	Curzon Street and surrounding streets	Low	Proposed scheme	Surface water runoff increased from proposed scheme to be attenuated prior to discharge into STW sewers.
Groundwater	Superficial deposits in Tame valley Washwood Heath (Bromford tunnel west portal and approach)	Medium High groundwater in superficial deposits	Bromford tunnel west approach and portal	No historical incidents of groundwater flooding. Tunnel approach barrier to groundwater flow.

7 Flood risk management measures

7.1.1 The purpose of this FRA is to demonstrate that within CFA26, the Proposed Scheme will not increase flood risk to any third party land owners and that the Proposed Scheme can be implemented without putting proposed infrastructure at risk of flooding.

7.1.2 To do this a number of physical mitigation measures have had to be included in the design to either safeguard adjacent land users or the Proposed Scheme and associated infrastructure. These physical measures are described below

7.1.3 Curzon Street station will interrupt surface water flow. Architectural features can mitigate the risk of flooding in areas where the risk is increased. Further linear drainage can be introduced where required in order to take flows away from the building.

7.1.4 The risk of flooding from rivers and streams (river flooding) has been assessed and the water level generated by the 0.1% AEP river flood events has been calculated. The Proposed Scheme rail level has been set a minimum of 1m above this level. This cannot be achieved on the southern and western side of Washwood Heath depot and so a retaining wall has been incorporated into the design. A minimum 300mm freeboard has been added onto the height of this wall in addition to the 0.1% AEP flood level. River hydraulic modelling of this infrastructure has been undertaken to make sure it does not increase flood risk to third parties at lower return period flood events.

7.1.5 The Proposed Scheme makes it necessary to divert the existing River Rea Overflow Channel. A new diverted channel has been designed. River hydraulic modelling of this makes sure this change to the river regime does not increase flood risk throughout the system.

7.1.6 A tunnel is proposed through the Bromford area. The portals to the tunnel will be located in (west) Washwood Heath depot and (east) in an industrial area to the south of Jaguar Land Rover. Walls are proposed around the portals to provide additional protection from inundation for the River Tame. The walls will be set at the 0.1% AEP flood level plus 300mm freeboard. The tunnel portals will include pile walls extending through the superficial deposits into the underlying Mercia Mudstone, initial numerical groundwater modelling has identified the risk of a long term increase in groundwater levels which may cause localised shallow groundwater conditions or groundwater flooding without mitigation. Recommendations are made to further investigate this risk during the design process.

7.1.7 Surface water management across the package is being provided to protect the Proposed Scheme up to the 0.1% AEP rainfall event by providing a collection and conveyance system. This system will be connected to attenuation areas that will safeguard third party land by ensuring surface water discharges do not increase up to the 1% AEP plus CC rainfall event.

8 Post-development flood risk assessment

8.1 River Flood Risk

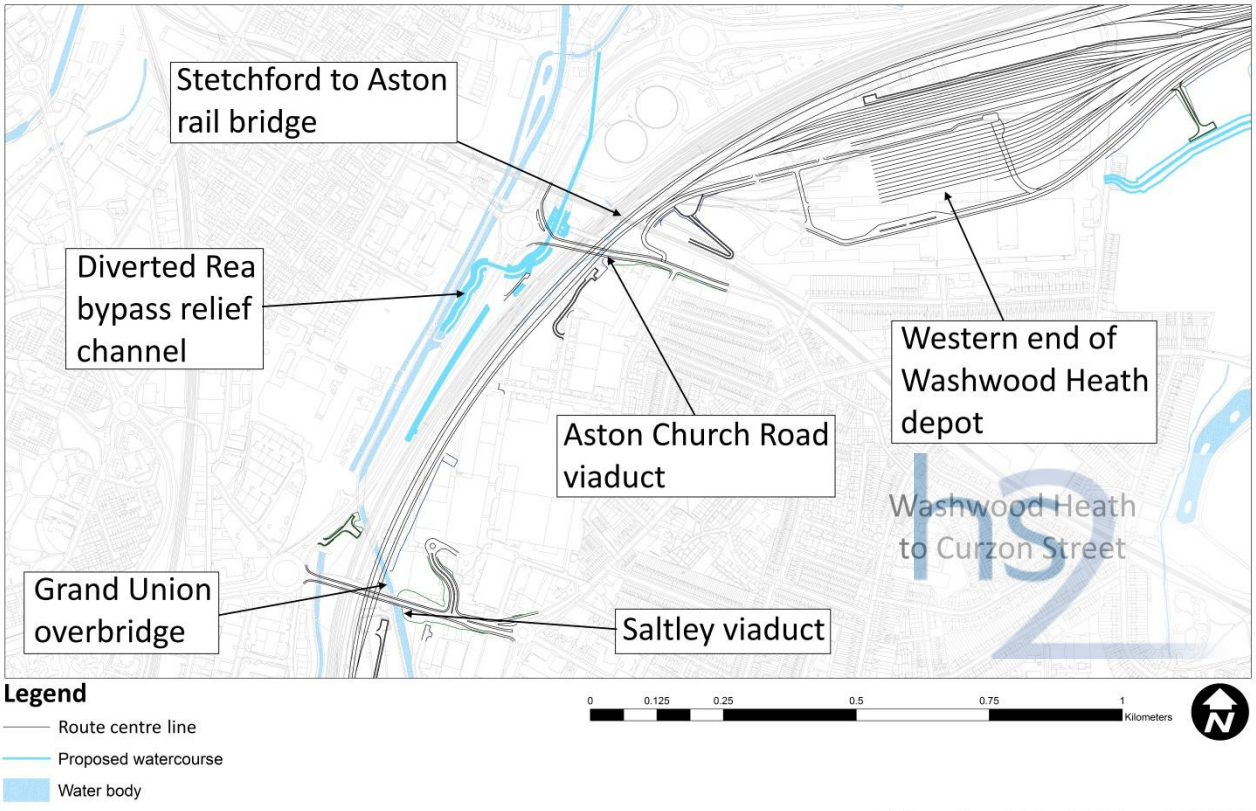
River Rea

8.1.2 The key design elements with potential river flood risk considerations associated with the River Rea are:

- the redesign of B4114 Saltley Viaduct;
- the Proposed Scheme crossing of the Grand Union Canal downstream of B4114 Saltley viaduct;
- the route of the Proposed Scheme between B4114 Saltley viaduct and Aston Church Road;
- diversion of the River Rea Overflow Channel;
- the redesign of the Aston Church Road crossing; and
- the western end of Washwood Heath depot.

8.1.3 These features are indicated in Figure 10:

Figure 10: Proposed Scheme design features with potential to affect the flood risk associated with the River Rea.



8.1.4 The Proposed Scheme has been incorporated into the baseline river hydraulic model of the River Rea to produce a post development model. The flood extents generated by the post development model for the full range of return period floods are included in maps WR-05 and WR-06 (Volume 5, Water resources map book)..

8.1.5 The flood extent shown on Volume 5: Map WR-05-160 G7 indicates additional flooding being generated after the scheme has been incorporated into the model immediately upstream of the Birmingham and Derby Line. This is a result of a 4mm rise in water level in the channel causing additional flood extent and depth. This is a consequence of the status of the current model which is only partially represent flow paths to the Grand Union Canal downstream. At the detailed design stage additional modelling and survey data collection will be undertaken to demonstrate that there is no significant increase in flood risk at this location.

8.1.6 The impact of each of the key design elements with a potential river flood risk consideration are examined in detail in the following sections.

Redesign of B4114 Saltley Viaduct

8.1.7 The B4114 Saltley Viaduct is an existing arch viaduct that supports a highway over the following features:

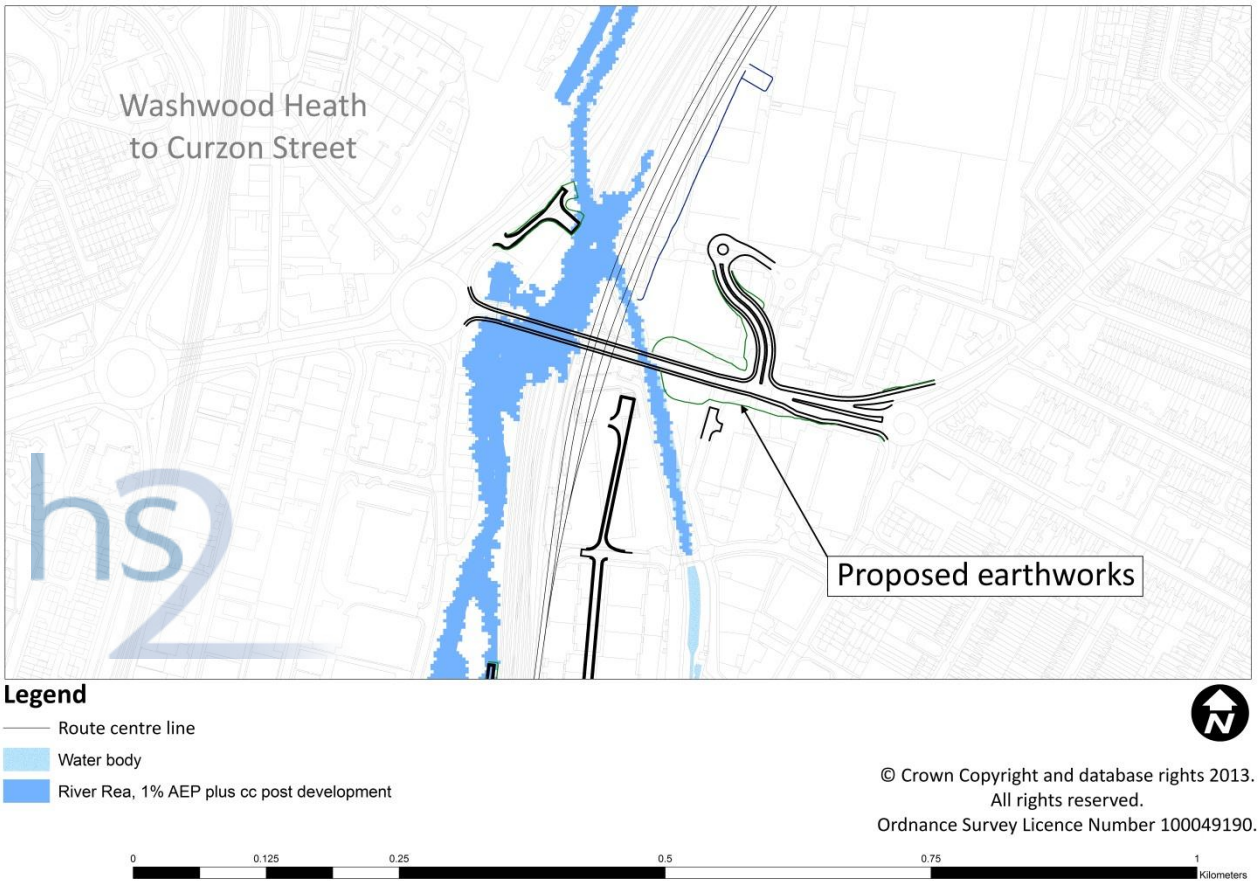
- River Rea;
- existing Network Rail infrastructure; and
- the Grand Union Canal.

8.1.8 The proposed Saltley viaduct will span the features above, in addition to the Proposed Scheme. The proposed earthworks to the east of the viaduct are outside the floodplain and therefore will not alter flood risk in this location. The soffit of the viaduct will be designed to the 1% AEP plus climate change flood level plus 600mm of freeboard.

8.1.9 The existing structure is a multi-arch viaduct which allows flood flows to pass underneath. The proposed structure will have a less frequent pier arrangement.

8.1.10 The soffit of the viaduct will be approximately 9m above ground level and the post development modelling indicates that the 1% AEP plus CC flood extent remains unchanged and the proposed earthworks are outside of the flood extent. Therefore, this design element will not affect the flood risk posed by the River Rea. This is illustrated in Figure 11.

Figure 11: Flood extent for the 1% AEP plus CC flood event at Saltley viaduct, post development model result



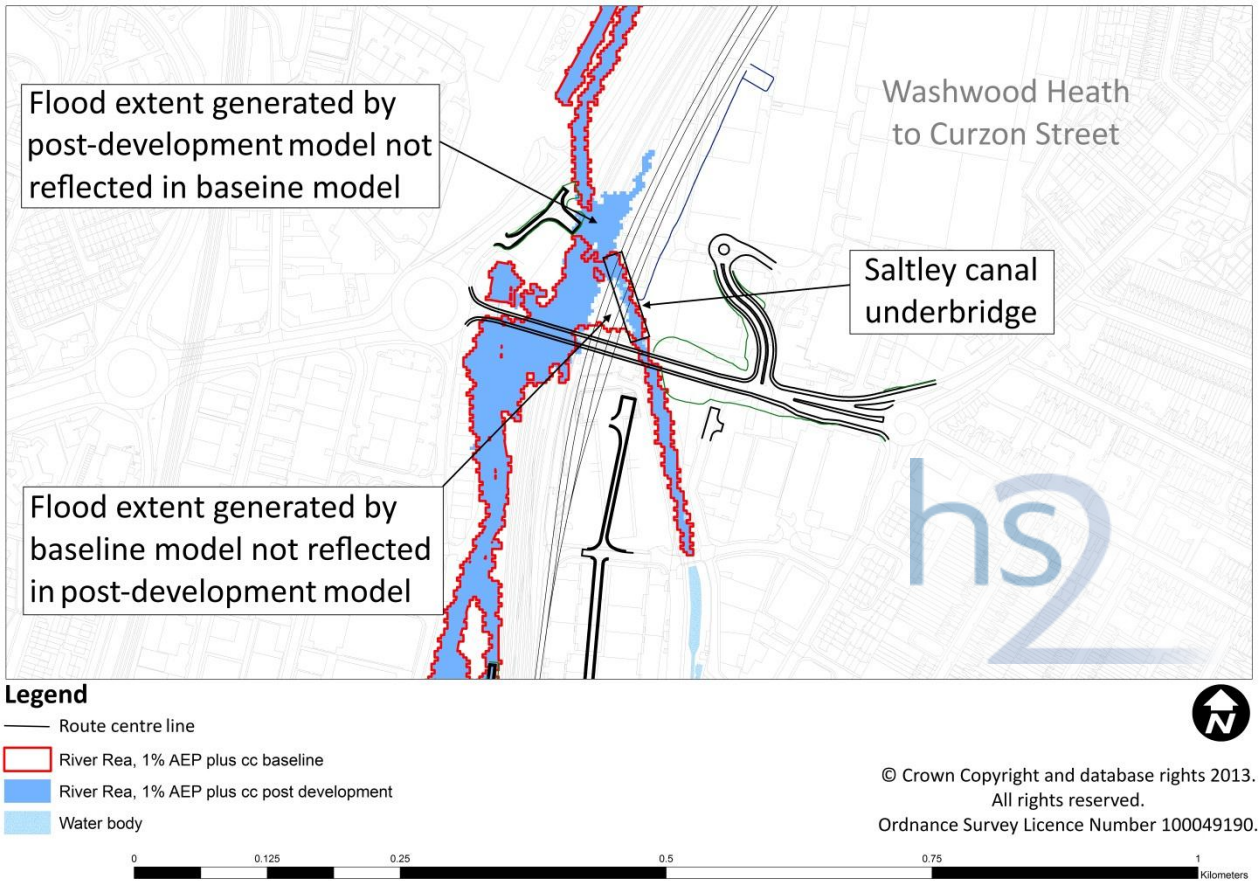
Grand Union Canal

8.1.11 Downstream of Saltley viaduct, the Proposed Scheme will cross over the Grand Union Canal. The baseline modelling of this area indicates that during the 1% AEP plus CC flood event the canal is a receptor for out of bank flows in this area. The proposed design of this crossing retains these flow paths.

8.1.12 The post development modelling results for the 1% AEP plus CC flood event indicate that flood waters extend further along the existing railway. This is a change from the baseline flooding extent. This is illustrated in Figure 12 which shows the flood outlines generated by the baseline and post-development models for the 1% AEP plus CC flood event for comparison.

8.1.13 The design in this zone (Figure 12) includes flow paths to permit discharge of flood waters into the canal; these are partially represented in the model due to its 6m grid size and available data. A review of the localised increase in flooding reported by the model indicates that there will be no significant change from the baseline provided that the preferential flow paths to the canal are maintained.

Figure 12: Flood extents for the 1% AEP plus CC flood event at Grand Union Canal Crossing, Baseline and post development model



The Proposed Scheme between Saltley viaduct and Ashton Church Road

8.1.14 The Proposed Scheme between Saltley viaduct and Ashton Church Road is such that it will form a barrier to out of bank flows from the River Rea across the floodplain to the east of the existing Birmingham and Derby railway. However, modelling indicates that floodplain flows do not occur for the River Rea in this location up to the 1% AEP plus CC event. The existence of the Proposed Scheme will not change the flood extent at this location. This is indicated in Figure 13.

River Rea Overflow Channel

8.1.15 The location of the route of the Proposed Scheme requires the realignment of the existing River Rea Overflow Channel. However the weir outlet from the River Rea will not be affected. The new channel will run immediately adjacent to the Grand Union Canal and flow northwards for approximately 170m before turning sharply to the east, passing under the A47 Heartlands Parkway within a new culvert.

8.1.16 It will then flow between the A47 Heartlands Parkway and existing railway towards Aston Church Road before passing under this road in a new culvert and then into the existing long culvert under the Gas Works at Watson Street. The existing culvert will continue to operate as it does now and connect to the main river channel approximately 45m downstream of the where the river passes underneath the Grand Union Canal.

8.1.17 The model simulation for the 1% AEP plus CC indicates that this diverted channel does not affect the flood risk posed by the River Rea up to the 1% AEP plus CC event. This is also indicated in Figure 13.

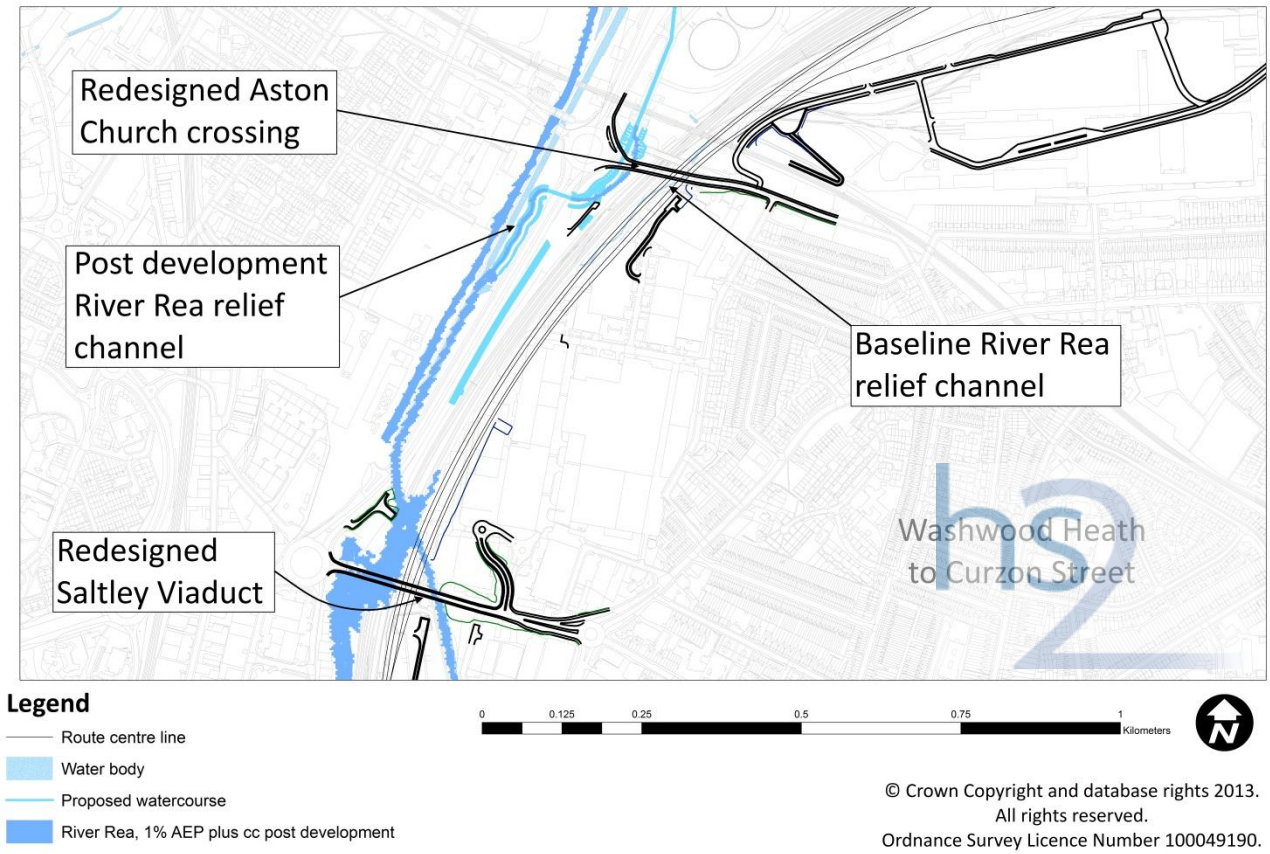
The redesign of the Aston Church Road crossing

8.1.18 The existing Aston Church Road crossing supports this road which crosses the River Rea Overflow Channel and Birmingham and Derby railway.

8.1.19 The new structure will span the diverted River Rea bypass overflow, the existing Birmingham and Derby railway and the Proposed Scheme.

8.1.20 The elements of this design with the potential to affect the flood risk posed by the River Rea is the soffit level of the viaduct and earthwork located to the east of the existing Birmingham and Derby railway. However, the post development modelling indicates that the soffit will be approximately 9m above the 1% AEP plus CC flood level and the proposed earthworks will be outside the 1% AEP plus CC return period flood extent. Therefore, this design element will not affect the flood risk posed by the River Rea. This design element is again shown in Figure 13.

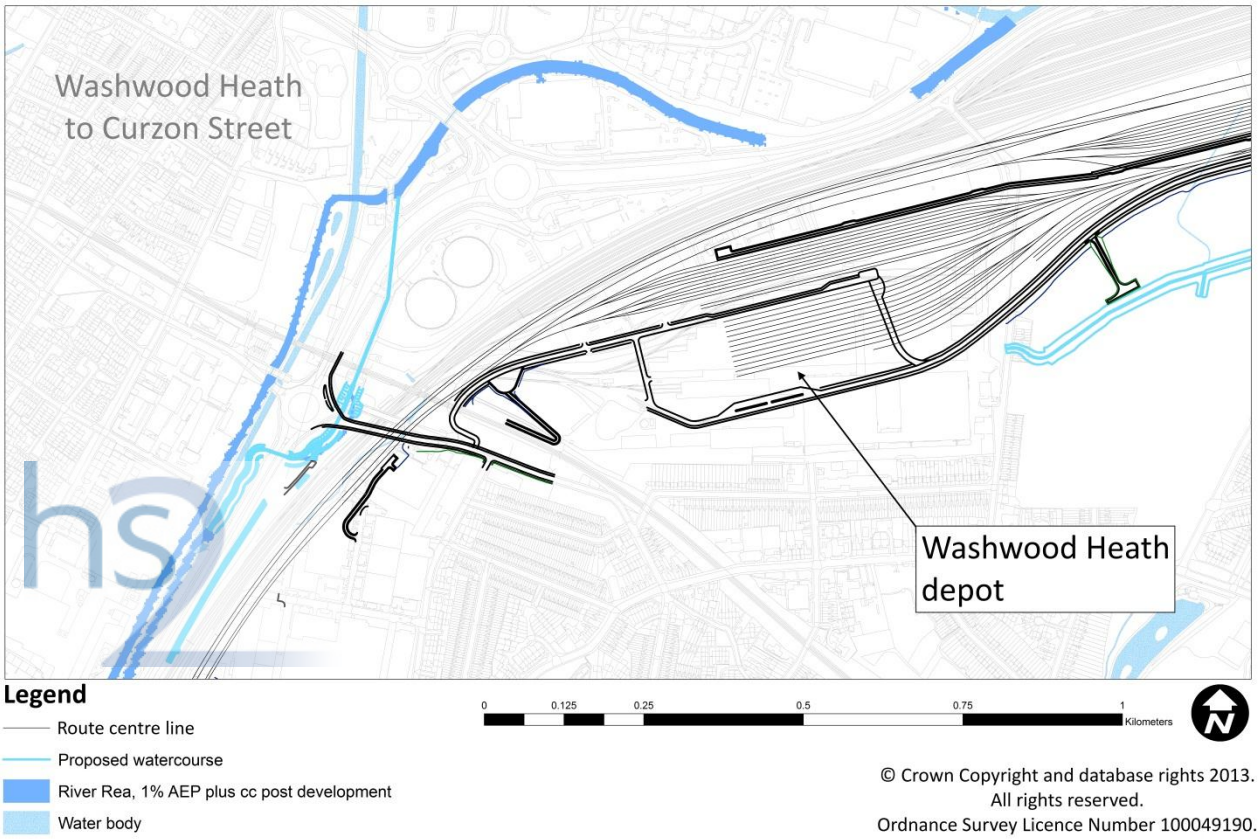
Figure 13: Flood extent for the 1% AEP plus CC for Saltley viaduct to Aston Church Road and the River Rea Overflow (relief) Channel diversion, post development model



Western End of Washwood Heath depot

8.1.21 The design of Washwood Heath depot involves raising ground levels of the site. This has the potential of impeding existing surface water flow routes that could be exploited by out of bank flows from the River Rea. However, the baseline and post development modelling indicates that the proposed Washwood Heath depot is outside the 1% AEP plus CC return period flood extent. Therefore, the works will not affect the flood risk posed by the River Rea. This is indicated by Figure 14.

Figure 14: Flood Extent for the 1% AEP plus CC in relation to Western End of Washwood Heath depot, post-development model.



River Tame

8.1.22 The proposed infrastructure required for the Proposed Scheme has been incorporated into the baseline river hydraulic model of the River Tame to produce a post development model. The full range of flood events have been simulated within this model to determine the impact caused by the Proposed Scheme on the performance of the River Tame during extreme flood conditions.

8.1.23 However, the modelling outputs generated have not been issued or formally approved by the Environment Agency. At this stage of the design process the River Tame baseline modelling outputs shown in this FRA and the accompanying drawings are only relevant to use in the context of the Proposed Scheme.

8.1.24 The design elements that have a flood risk consideration associated with the Tame or its tributaries (other than the Rea) are:

- Washwood Heath depot;
- Bromford tunnel west portal;

8.1.25 The river flood risk considerations associated with these design elements are examined in the following sections.

Washwood Heath depot

8.1.26 The key river flood risk considerations associated with the proposed Washwood Heath depot are listed below and shown in Figure 15:

- the proposed diversion of the Washwood Heath Brook; and
- Protection of Washwood Heath depot from inundation up to the 0.1% AEP flood event.

8.1.27 Washwood Heath brook, predominately functions as an urban drainage channel. It has been designed to ensure its capacity is sufficient and that there will be no significant increase in flood risk. It is not included in the current hydraulic model of the River Tame.

8.1.28 It is proposed to divert the Washwood Heath Brook along the southern boundary of the depot. Consequently it will enter the Tame at a new location downstream of Bromford Lane. This channel is also designed to accept the surface water discharges that flow into the existing drain along Common Road, which accepts surface water flows from the south and the west.

8.1.29 In addition, the level of the Washwood Heath depot has been increased to ensure it is operable up to and including the 0.1% AEP flood event and that the rail levels are at least 1m above the 0.1% AEP flood levels.

8.1.30 The flood waters from the Tame prevented from accessing the existing Washwood Heath Brook channel as a result of the depot will be accommodated in the proposed watercourse diversion. This has been sized to allow this to be achieved without compromising its ability to accept river and surface water flows.

8.1.31 The post-development River Tame model demonstrate that the Washwood Heath depot is not at risk of inundation from the River Tame and its establishment does not increase flood risk up to and including the 1% AEP plus CC flood event.

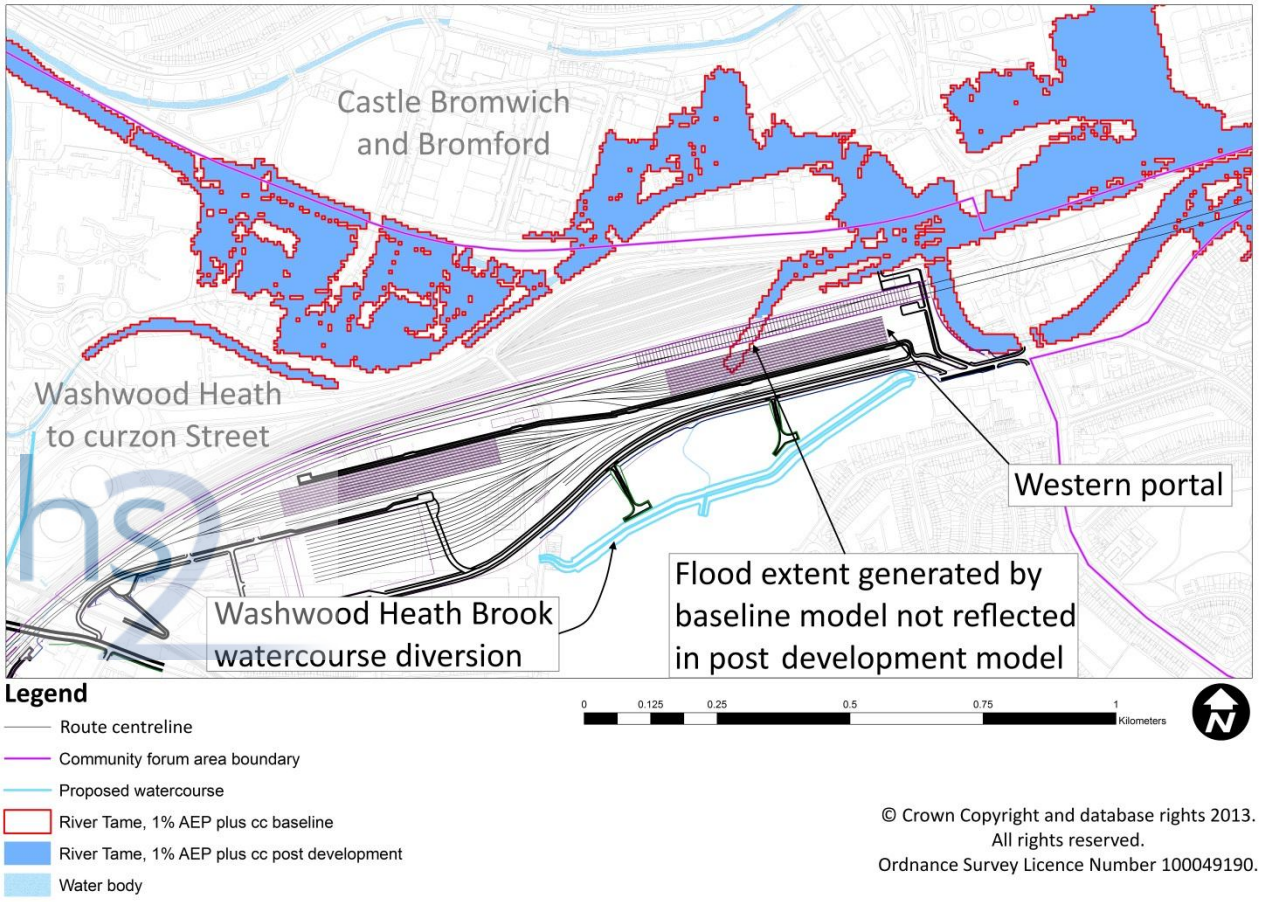
Bromford tunnel west portal

8.1.32 The portals of the proposed tunnels are very sensitive to flood risk as the consequences of inundation will be very high. The Bromford tunnel west portal is located adjacent to the Washwood Heath depot and will be protected from inundation from the River Tame up to and including the 0.1% AEP. The post development flood extents indicate that the proposed works will not increase flood risk to third party land up to the 1% AEP plus CC event as indicated in Figure 15.

8.1.33 The tunnel portals include piled retaining walls extending through the superficial deposits into the underlying Mercia Mudstone, initial numerical groundwater modelling has identified the risk of a long term increase in groundwater levels which may cause localised (200-400m to the south of the portal) groundwater flooding without mitigation (for further details refer to Volume 5: Appendix WR-004-020).

8.1.34 The retaining structure will be sealed to prevent the ingress of water and sub-surface drainage will be provided to mitigate the impacts from the structure on surrounding groundwater flows and levels. Subject to the correct implementation of all mitigation measures, no significant effects on groundwater within the superficial layer are predicted.

Figure 15: Flood extent for the 1% AEP plus CC flooding extent in relation to Washwood Heath depot and western tunnel portal for baseline and post development



8.1.35 Temporary works in the River Tame will be required to enable construction of the proposed tunnelling activity under the River Tame. This will involve the permanent installation of a concrete slab below the existing river bed after which the river bed will be reinstated.

8.1.36 The western tunnel portal is immediately adjacent to the River Tame with the proposed tunnel passing under the river perpendicular to the channel. At this location, under baseline conditions, the river Tame remains in bank up to and including the 1% AEP plus CC. To permit construction of the Proposed Scheme temporary works will be required in the river channel that reduce its capacity, as a result localised temporary raising of the river banks will be required to pass flood events up to a 10% AEP with no significant increase in flood risk. The in channel temporary works will be designed in order to allow reinstatement of the existing channel capacity in the event of flood events greater than the 10% AEP thus avoiding significant increases in flood risk to the construction works or third parties up to the 1% AEP plus CC. Early warning measures for flood events greater than 10% AEP will be instigated to ensure that adequate time is available to permit the reinstatement of the existing channel capacity.

8.2 Surface water and sewerage flood risk

8.2.1 This section describes how surface waters generated by the Proposed Scheme and associated infrastructure, such as highway diversions, Washwood Heath depot and Curzon Street station, will be managed to ensure the Proposed Scheme is not at risk of inundation during all flood events up to the 0.1% AEP.

8.2.2 In addition, a description is given of the risk posed by surface waters to third party land taking account of where the Proposed Scheme or associated infrastructure disrupts existing infrastructure and drainage paths.

Proposed surface water infrastructure/sewerage

Route wide within CFA26

8.2.3 At this preliminary design stage the surface water management strategy for railway infrastructure has been based on a conveyance system with sufficient capacity to collect and convey surface water to attenuation areas for all events up to the 0.1% AEP rainfall event. In this way the Proposed Scheme will be protected.

8.2.4 Ponds are the preferred method of flow balancing due to the linear nature of the project and the requirement to control run-off at managed discharge points (design drawings are shown in CT-06 of the Volume 2 Map Book).

8.2.5 Based on the available information at the time of writing and due to the likely presence of contaminated ground combined with high groundwater levels it is highly unlikely that infiltration techniques will be a viable method of surface water disposal in this section of the route. Site investigations will be undertaken as the design progresses.

8.2.6 Within CFA26, the Proposed Scheme drainage system will entirely discharge to watercourses. There are no surface water outfalls anticipated to public sewers.

8.2.7 The attenuation areas have been sized for the 1% AEP plus CC rainfall event, assuming a discharge rate that matches the existing conditions with a 20% reduction in accordance with BCC requirements. This is a local requirement to manage capacity issues within the current system. Where there are undeveloped areas the discharge is restricted to greenfield rates. For surface water management the climate change allowance has been taken as a 30% increase in rainfall intensity.

8.2.8 Discharge rates from each catchment have been calculated based on the method described in the Institute of Hydrology Report 124 (1993)[28], adopting appropriate urban factors for developed areas. This method has been employed in the way described in Interim Code of Practice for Sustainable Drainage Systems (2004)[29].

[28] Marshall, D.W.C. and Bayliss, A.C. (1993), *Flood Estimation for Small Catchments report number 124*, Natural Environment Research Council.

[29] National SUDS Working Group (2004), *Interim Code of Practice for Sustainable Drainage Systems*, CIRIA

8.2.9 The attenuation storage calculations for the Proposed Scheme have assumed a high run-off coefficient, (i.e. the majority of the rainfall landing on the ground will enter the drainage system).

8.2.10 Where the adjacent land falls towards the railway (or there are existing urban drainage systems that may divert flows towards the railway), a cut off drainage system and threshold protection measures are provided to intercept the flows from external catchments and divert them to the nearest crossing point of the route, usually a bridge or culvert conveying a watercourse under the Proposed Scheme.

8.2.11 At the Bromford tunnel western and eastern portals, sections of the railway are too low to outfall by gravity and require pumping stations to lift surface water run-off to ground level prior to being discharged to watercourses.

8.2.12 'Emergency' or 'part time' surface pumping stations will also be required at sections of railway. The system will drain by gravity most of the time, but where flood walls are installed and the rail levels are less than 1m above the 0.1% AEP river water levels, pumping will be required during periods when river levels are high. This will require the installation of non-return valves on the outfall pipes so that flood water does not backflow in to the railway drainage during these river events.

8.2.13 A separate pumping station will lift groundwater and run-off from maintenance activities (and during emergencies only, water from fire protection systems) from the lowest point of the tunnel itself to ground level, from where it is discharged to the public foul sewer near the west portal at Washwood Heath. Attenuation will be provided if necessary.

8.2.14 The surface water flow resulting from the land east of the Proposed Scheme between Aston Church Road and Saltley Road will be collected into flood relief culverts running from east to west will run under the route of the Proposed Scheme and existing Birmingham and Derby Line connecting to an open channel which discharges into the proposed River Rea Overflow Channel.

8.2.15 The railway drainage in the section on the approach to Curzon Street station will be on elevated viaducts. This is collected and discharged to water bodies in a similar way to other parts of the railway drainage system.

8.2.16 The railway drainage catchments are listed in the table below and shown in Annex B.

Table 5: Railway Drainage Catchments and Outfalls

Linear km or plan area of route drained	**Description**	**Receiving watercourse**	**Watercourse status**	**Brownfield peak discharge rate Q100 (l/s/ha)***	**Post-development peak discharge rate Q100/A (l/s/ha)****	**Outfall No.**
0.84	Pumped (tunnel portal)	Diverted Washwood Heath Brook	Ordinary	3.3 - 22.7	2.6 - 18.2	O-1690
28.3 ha (area)	Gravity(depot)	Diverted Washwood Heath Brook	Ordinary	3.3 - 22.7	2.6 - 18.2	O-1712

Linear km or plan area of route drained	Description	Receiving watercourse	Watercourse status	Brownfield peak discharge rate Q100 (l/s/ha)*	Post-development peak discharge rate Q100/A (l/s/ha)**	Outfall No.
1.51	Gravity (and emergency pumping station to River Rea overflow)	Diverted Washwood Heath Brook	Ordinary	3.3 - 22.7	2.6 - 18.2	O-1722
0.53	Gravity (& emergency pumping station to River Rea)	River Rea	Main	3.3 - 22.7	2.6 - 18.2	O-1730
0.38	Gravity	River Rea	Main	3.3 - 22.7	2.6 - 18.2	O-1733
0.21	Gravity	River Rea	Main	6.8 - 22.7	5.4 - 18.2	O-1738
0.51	Gravity	River Rea	Main	3.3 - 22.7	2.6 - 18.2	O-1743
0.67	Gravity	River Rea	Main	3.3 - 22.7	2.6 - 18.2	O-1749

Notes: *Q100/A is the 1 in 100 year peak discharge rate of run-off per unit area, derived from QBAR estimation for urban catchments with Urban Growth Factor applied (ICoP and IoH 124 cl 7.3). **Allowable post development discharge rate is the brownfield Q100/A with 20% betterment.

Curzon Street station

8.2.17 The surface water drainage system will be provided for Curzon Street station. As with the route wide condition, discharge will be restricted to existing run-off rates up to the 1% AEP plus CC rainfall event with a 20% reduction in accordance with BCC requirements for areas currently developed and restricted to greenfield rates for undeveloped areas.

8.2.18 Curzon Street station will be served by a positive segregated foul and surface water drainage system. Surface water will be collected from the building roofs via above ground drainage and via surface water drains from adjacent hard standing and will be collected in a buried pipe system mostly aligned with building perimeter.

8.2.19 Flows will be attenuated in below ground geo-cellular or oversized pipe storage systems and subsequently discharge into the adjacent STW sewers via the agreed number of connection manholes at various agreed discharge rates. Attenuation storage will be placed at suitable locations close to the connection points either around or under the building such as:

- landscaped strip parallel to the northern facade of the building;
- delivery area at western part of the lower entrance floor ;
- taxi drop off; and
- pavements along the eastern building elevation.

8.2.20 Due to the space constraints within and around the site open storage features will be not viable. Infiltration of the surface water is not considered as a feasible method of the surface water disposal due to the ground conditions (i.e. the ground conditions are such that infiltration is not possible).

8.2.21 Rainwater harvesting will be implemented on site as a combined system with surface water attenuation. Rainwater run-off from the building roof will be conveyed to below ground tanks and be treated prior re-use.

8.2.22 Run-off from adjacent roads and paved areas will not be presented for re-use and shall be kept separate to prevent possible contamination and silting of the system.

Table 6: Curzon Street station Drainage Catchments and Outfalls

Catchment area (ha)	**Attenuation volume (m^3)**	**Proposed discharge (l/s)**	**Outfall**
1.33	500	74	Park Street
2.22	1450	23	Split between an outfall at Bartholomew Street and New Canal Street
1.46	480	114	Banbury Street

Washwood Heath depot

8.2.23 The surface water drainage design for the proposed development is to provide a contemporary drainage system. For the design of the proposed Washwood Heath depot the effective catchment will be taken as the sum of the track and impermeable areas plus the effective area of any permeable and sloping surfaces. The feasibility of incorporating infiltration has been discounted at this preliminary stage. This will be confirmed once precise geotechnical information becomes available.

8.2.24 As with the route wide condition discharge will be restricted to existing run-off rates up to the 1% AEP plus CC rainfall event with a 20% reduction in accordance with BCC requirements for areas currently developed and restricted to greenfield rates for undeveloped areas.

8.2.25 All surface water generated within the proposed development plots will be managed by new or existing drainage infrastructure. Final arrangements will be developed in conjunction with finished levels.

8.2.26 Washwood Heath depot will be served by positively draining segregated foul and surface water drainage. Track areas will be drained by combined filter and carrier pipes, discharging to a primary carrier pipe system running beneath the site access roads.

8.2.27 Surface water run-off from roads and building roofs will be collected in a buried pipe system aligned where possible within open spaces or beneath the site access roads. Flows (including contributions from the track area) are conveyed to a large above ground water storage basin located south-west of the maintenance centre.

8.2.28 Rainwater harvesting techniques will implemented on site. Roof run-off from the covered stabling yard and other discrete buildings will be conveyed to below ground tanks for re-use. Run-off from road and track areas will not be presented for re-use and shall be kept separate to prevent possible contamination.

8.2.29 Pollution control will be provided where necessary, the proposed locations will be determined during detailed design.

Existing surface water infrastructure/sewerage

Route wide within CFA26

8.2.30 The Proposed Scheme requires the diversion or replacement of a number of existing public highways. The associated highway drainage systems will require reconfiguration or replacement. However, in this section no completely new highway surface water outfalls to public sewers or other water bodies are anticipated.

8.2.31 Between the Stetchford and Aston railway and Curzon Street the following principal sewers outfalling to the River Rea Overflow Channel are affected by the Proposed Scheme:

- 2.75m diameter surface water sewer;
- 0.675m diameter combined sewer; and
- 0.45m diameter overflow pipe from a CSO located in Aston Church Road.

8.2.32 These sewers require local diversion under the Proposed Scheme but their routes to the Rea Overflow Channel are maintained. The CSO serves a larger 1.2m diameter combined sewer (Saltley West trunk) which crosses under the Proposed Scheme near the existing railway line.

8.2.33 The 0.675m diameter combined sewer will require a local diversion. Nevertheless its route to the existing Minworth treatment works will remain unchanged.

8.2.34 A significant combined sewer comprising of four 1200mm diameter pipes pass through Proposed Scheme at the Eastern Portal. This feature will have to be diverted in advance of commencing tunnelling works.

Curzon Street station

8.2.35 With regards to the proposed station, it is assumed that public sewers in the following roads will need to be diverted, curtailed or abandoned:

- Freeman Street;
- Park Street;

- Fazeley Street;
- Bartholomew Street;
- Banbury Street; and
- New Canal Street.

8.2.36 The proposed surface and foul water system will take account of these and ensure that flood risk is not increased by this activity.

Washwood Heath depot

8.2.37 There are two major combined sewers crossing the Proposed Scheme and the new depot:

- 0.90m diameter combined sewer (Saltley East trunk); and
- 0.825m diameter combined sewer (Saltley West trunk)

8.2.38 Due to the reduced levels of the western depot and the Proposed Scheme/depot track vertical alignments both these sewers will diverting to pass under the new construction.

Surface water flow flood risk

8.2.39 The design seeks to replicate existing catchment distributions and minimise alterations to surface water flow paths from their existing routes. Where this is not possible, a safe and secure route for drainage systems and surface water flows has been identified such that there is no increased flood risk to properties or businesses.

8.2.40 Where the Proposed Scheme is above ground it runs parallel to the Rivers Tame and Rea and is predominantly located either within or on the margins of the floodplains of these rivers. It also runs alongside the existing railway, which in itself is a continuous linear feature that forms a barrier to drainage paths and drainage systems.

8.2.41 Key locations are analysed in the sections below.

Stetchford and Aston railway and Curzon Street station

8.2.42 Between Stetchford and Aston railway and Curzon Street station the proposed depot reception tracks and the Proposed Scheme are in cutting with flood walls which form a barrier to existing watercourses and surface water flows which traverse from south to north towards the River Rea Overflow Channel.

8.2.43 There is also potential for exceedence flows from local sewers and river flows from the upstream River Rea to be impounded between the Proposed Scheme and the railway embankment. To convey these potential surface water flows, flood culverts are provided across and under both the route of the Proposed Scheme and the existing railway at Dorset Road.

8.2.44 A new surface water channel parallel to the north side of the existing railway connects both the existing surface water sewers and the flood culverts to the diverted River Rea Overflow Channel.

Curzon Street station

8.2.45 The proposed station building interrupts the existing north-south surface water flow routes across the area. Where this occurs new routes are provided around the building that do not increase flood risk to existing properties and businesses.

8.2.46 The natural direction of the surface water flow is diagonally through the centre of the development. There is a potential flood risk posed to the northern perimeter of the station as well as the proposed New Canal Street underpass.

8.2.47 The current building design assumes that the underpass can be used as a safe route for managing excess surface water. Therefore, detailed surface water flow modelling will be required to determine potential depths and velocities through the underpass investigate additional flood protection measures required.

Washwood Heath depot and Bromford tunnel west portal

8.2.48 In this section the new Washwood Heath depot, associated depot tracks and the vertical alignment of the Proposed Scheme sever two existing water courses the Washwood Heath Brook and an open channel that receives highway drainage at Common Lane. Both of these flow south to north and feed into the River Tame. They are served by urban drainage and sewerage systems.

8.2.49 The proposal is to divert and combine these two features along the southern boundary of the depot with a connection to the River Tame near Bromford Lane, approximately 200m downstream of the current Washwood Heath confluence with the Tame.

8.2.50 A new perimeter drainage ditch located at the top of the depot cutting intercepts flows from the exterior catchment to the south and directs it towards the new watercourse diversion at Common Lane.

8.2.51 Surface water flows from the proposed depot site onto surrounding development will be managed by the proposed drainage system. Particular attention will be paid to any area sloping towards the plot boundaries, including the new site accesses, where flows will be intercepted by surface collection infrastructure. Extra surface water collection measures will implemented where required, including interception ditches at the site boundary.

8.3 Groundwater

8.3.1 It is assumed that the principal mechanism by which the Proposed Scheme may increase groundwater flood risk is where impermeable structures (e.g. lined tunnels and pile walls) act as a barrier to groundwater flow and have the potential to cause a rise in groundwater level with mounding in the vicinity of these structures. Other changes to the groundwater environment such as through drained cuttings are not assumed to increase the groundwater flood risk as the drainage element is assessed as part of the post-development drainage system.

8.3.2 To assess the possible changes to groundwater levels and flows, and the associated change in groundwater flood risk, a high level assessment (see Volume 5: Appendix WR-004-020 for the findings of the initial groundwater modelling) of the groundwater conditions along the route has been undertaken to understand where the Proposed Scheme is likely to interact with groundwater (i.e. it is on an aquifer and within the proximity of groundwater levels). These areas have the potential to increase relative groundwater flood risk although further assessment of the proposed design and structures is made to confirm whether a change in groundwater flood risk is likely. Further field data collection and analytical or numerical modelling is then recommended to quantify this change.

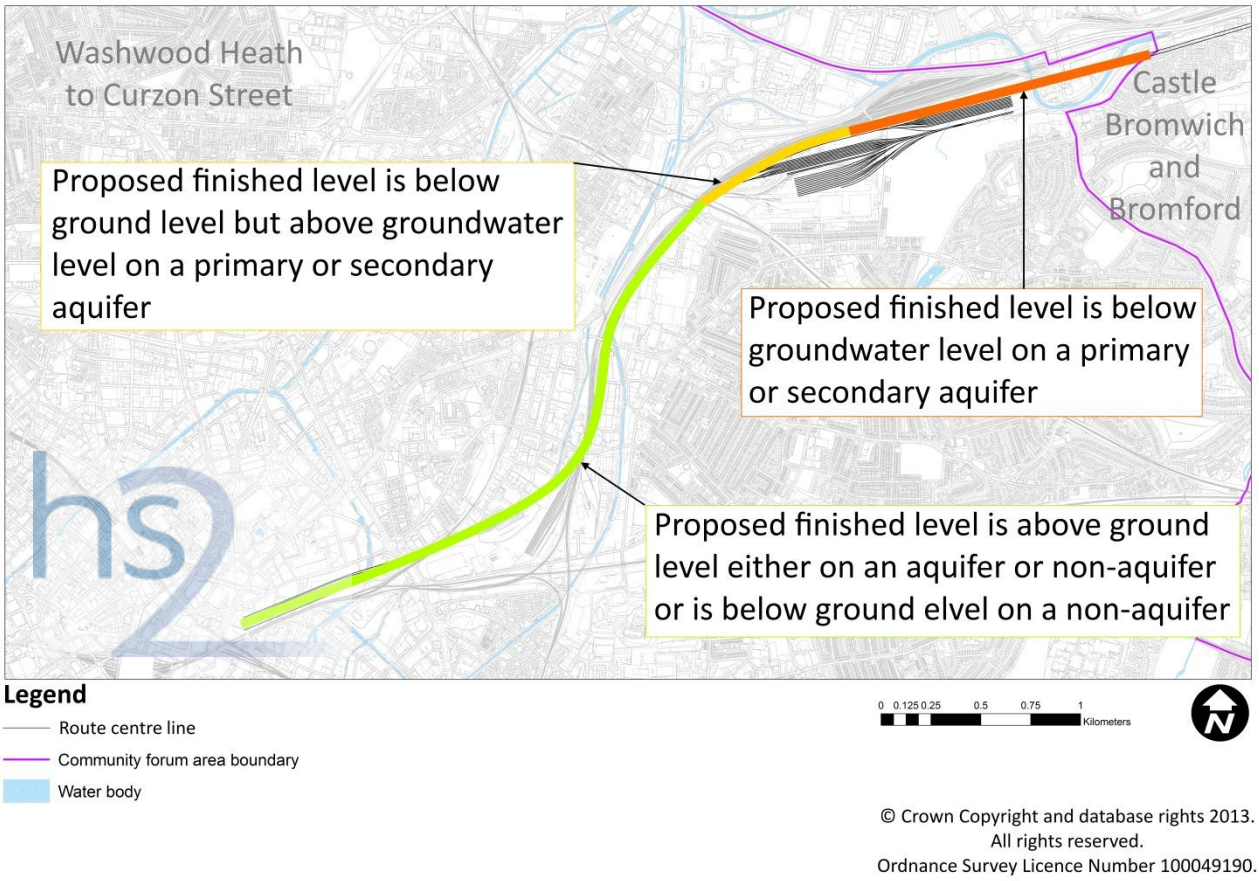
8.3.3 Table 6 shows the criteria used to identify areas where changes to the level of groundwater flood risk along the route corridor may occur from the introduction of the Proposed Scheme.

Table 7: Criteria to identify areas where changes to groundwater flood risk may occur

Low	Where the proposed finished level is above ground level either on an aquifer or non-aquifer or is below ground level but above groundwater level on a non-aquifer
Medium	Where the proposed finished level is below ground level but above groundwater level on a primary or secondary aquifer
High	Where the proposed finished level is below groundwater level on a primary or secondary aquifer

8.3.4 Information presented in Table 7, and summarised in Figure 16 illustrates the areas within CFA26 where there is greater potential for changes to groundwater flood risk post-development and elsewhere.

Figure 16: Areas of greater potential for changes to groundwater flood risk within Washwood Heath to Curzon Street



8.3.5 The main section of the route where there is an increase in groundwater flood risk is located at Washwood Heath where the proposed twin bore tunnel (Bromford tunnel) and portal passes through the Secondary aquifer superficial deposits. In this area the tunnel and portal have the potential to act as a local barrier to shallow groundwater flow which may cause mounding and a rise in groundwater levels. An initial numerical groundwater model has been developed to assess the potential change in local groundwater levels, and to inform design mitigation measures to control groundwater levels to an acceptable level.

8.3.6 The groundwater model indicates that without mitigation measures there may be a long-term increase in groundwater level within the superficial deposits in the area of the Bromford tunnel west portal, where the pile walls will act as a barrier to groundwater flow, potentially causing groundwater to emerge at ground level and causing flooding. The model predicts the Bromford Tunnel west portal approach will have the greatest impact with a simulated ponding of groundwater on the southern boundary of 2m and a drawdown of groundwater on the northern side of 2m. This is in an area where water strike information indicates existing groundwater levels are between 2 and 5 m depth. Water-proofing of the structure will be provided to the structure to prevent water inundation and sub-surface drainage will be provided to mitigate the impacts due to the

8.3.7 To the west of the Birmingham fault, although rising groundwater and relatively shallow groundwater levels have been identified as a risk, the Proposed Scheme is largely above ground.

Table 8: Summary of the conditions along the route corridor and areas where the groundwater flood risk may change

Approximate grid ref	Existing ground level (mOD)	Proposed level (mOD)	Assumed groundwater level (mOD)	Aquifer classification (Superficial)	Aquifer classification (solid geology)	Superficial geology	Solid Geology (approximate depth, m) at reference borehole	Title	Reference BH	Distance to Ref BH (m)	Assumed depth to groundwater level (m) at reference borehole	Assumed ground level (mOD) at reference borehole
SP1144 8900	90 - 92	92 - 72	87	Secondary A	Secondary B	Made ground, Alluvium (Peat, clay/gravel)	Mercia Mudstone (5 - 10)	Bromford tunnel west portal (retained cut)	various	N/A	2 - 3	n/a
SP0981 8900	93	91.7		Secondary A	Secondary B	Made ground, Alluvium, Till (clay)	Mercia Mudstone (6)	Washwood Heath rail overbridge	S2_05590_BH6/2	150	Unknown	93
SP0954 8876	92	91.8	91	Secondary A	Secondary B	Made ground, Alluvium (variable clay/gravel). glacioacustrine deposits (MMG)	Mercia Mudstone (5)	Aston Church Road overbridge	SP08NE1129	95	1	92
SP0915 8817	94.4	97.2	93.4	Secondary A	Secondary B	Made ground, Alluvium (clay), glaciofluvial deposits (sand and gravel)	Mercia Mudstone (>30)	Saltley Canal underbridge	SP08NE322	30	1?	92
SP0915 8802	94.6	97	92.6	Secondary A	Secondary B	Made ground, Alluvium (clay), glaciofluvial deposits (sands, gravels)	Mercia Mudstone (>30)	B4114 Saltley viaduct	SP08NE322	15	2?	94

SP0914 8787	95.7	103.3	93.7	Secondary A	Secondary B	Made ground, Alluvium (gravels)	Mercia Mudstone (6 but considerable variations in this area)	Curzon Street No.1 and 2 viaduct	SP08NE630 AND 632 (unknown GL)	20	2	98
SP0905 8765	98.3	113		Secondary A	Secondary B	Made ground, Alluvium (gravels)	Mercia Mudstone (6 but considerable variations in this area)	Duddeston Mill Road underbridge	SP08NE632 (unknown GL)	80		98
SP0904 8760	98.6	114.5		Secondary A	Secondary B	Made ground, Alluvium (soft to firm Glacial Till)	Mercia Mudstone (4 but considerable variations in this area)	Curzon Street No. 1 viaduct	SP08NE470 to 472 (unknown GL)	100	?	98
SP0842 8721	100.5	117.5	98.5	Secondary A	Secondary B	Made ground, Till, glaciofluvial deposits (gravels)	Mercia Mudstone (13) (apparent glacial channel)	Curzon Street No.2 viaduct	SP08NE2425	35	2	103
SP0831 8713	108.3	117	105.3	Secondary A	Secondary B and Principal	Made ground, Till, glaciofluvial deposits (gravels)	Mercia Mudstone/Bromsgrove Sandstone (11)	Curzon Street No. 1, 2 and 3 viaduct	SP08NE2872	50	3	108
SP0806 8703	109.6	116.9	104.6	Secondary A	Secondary B and Principal	Made ground, glaciofluvial deposits (gravely)	Bromsgrove Sandstone (5)	Curzon Street station	207688_BH103	0	5	112

8.4 Artificial sources/infrastructure

The Canal System

8.4.2 The canal system in the vicinity of the Washwood Heath to Curzon Street area poses a low risk to the Proposed Scheme. The Proposed Scheme will not change the risk of flooding due the canal system. This is based on an understanding of the relative levels of the canal system and the surrounding land taken for Ordnance Survey mapping sources and aerial photographs. Within Birmingham and its surrounds, the canal is at a lower level compared to the land in its vicinity and as such the canal is not reliant on large embanked sections that could breach with the exception of those detailed in Section 6.4.

8.4.3 The canal system could overtop causing localised flooding around the canal system. This is not considered a significant risk to the Proposed Scheme at any location.

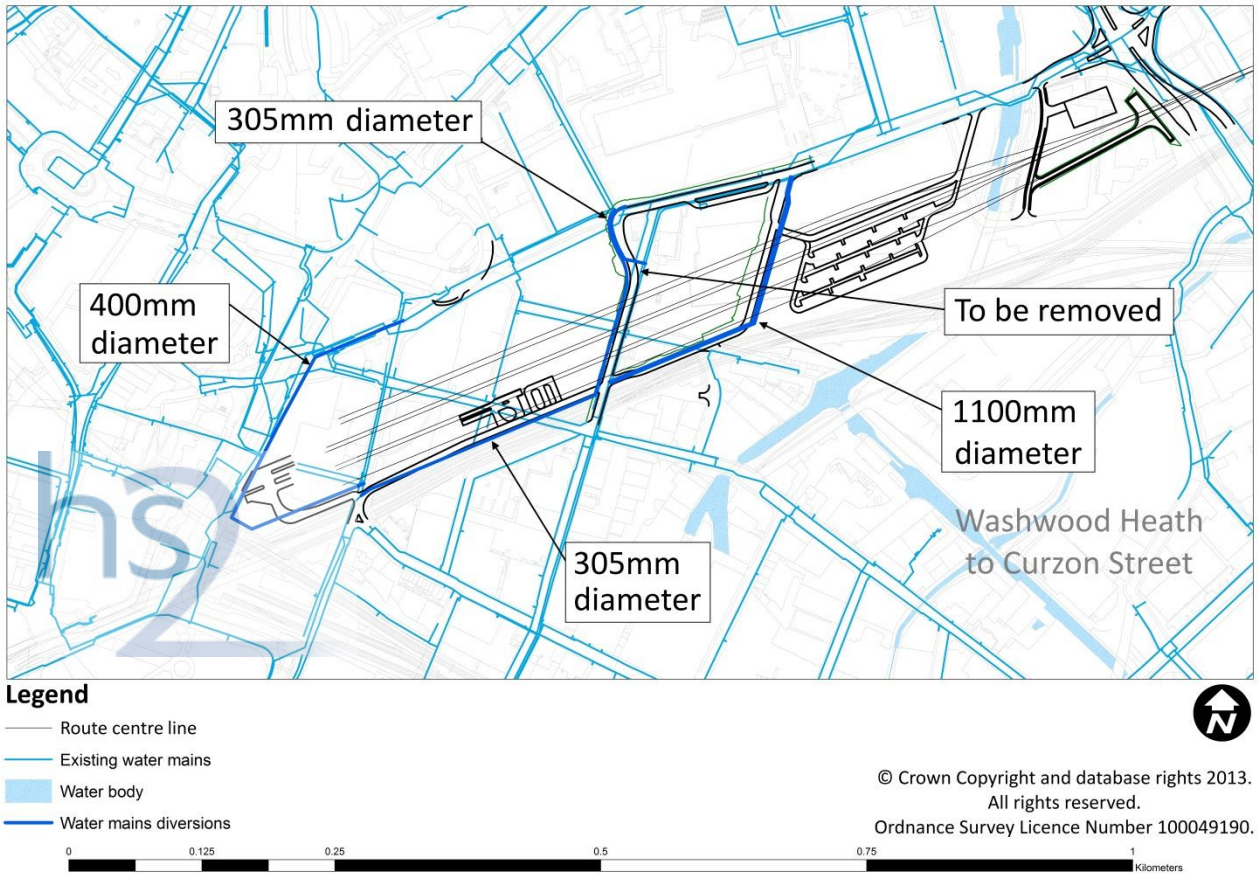
Water supply network

8.4.4 Overland flow has been adopted as a term in this section to distinguish it from surface water flooding i.e. where the capacity of the drainage system is exceeded. Overland flow in this section refers to flow over the surface which is caused by infrastructure failure.

8.4.5 Assets are mapped and where appropriate the potential overland flow paths inspected by interrogation of topographic data. The extent of overland flow from a burst water main will depend on discharge rate which is influenced by a number of factors including water main diameter, pressure, depth and upstream water source. Given the limited data available and complexity in accurately assessing overland flow routes this FRA is limited to identification of potential flow paths only.

8.4.6 Where existing or diverted water mains and water distribution infrastructure have been judged to offer a potential source of flood risk from an upstream catchment an assessment of potential surface water flow routes have been made of the risk associated with this source.

Figure 17: Curzon Street diversions

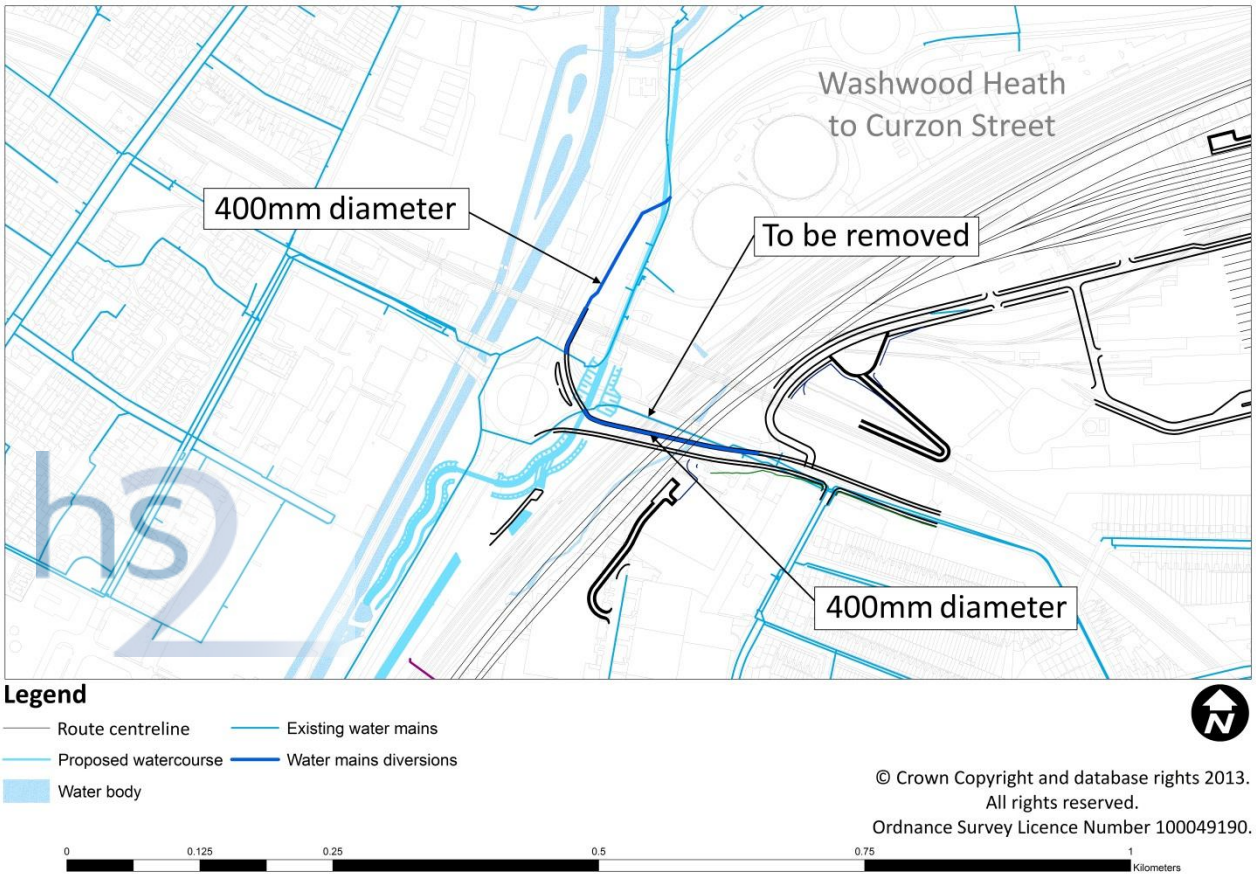


8.4.7 Two existing water mains of significance will be diverted at Curzon Street in 1100mm and 400mm diameter steel pipework respectively to avoid the proposed Curzon Street station building.

8.4.8 The closure of Park and Bartholomew Streets will concentrate the surface water flow path to New Canal Street therefore diversion of this 1100mm diameter water main will reduce the flood risk in this area.

8.4.9 Any resulting surface water flooding in the vicinity of local buildings to the south of the proposed works will match the existing situation.

Figure 18: Saltley diversions



8.4.10 There are two existing water mains in the Saltley area that will need to be diverted. A 400mm diameter steel pipe in both the realigned Aston Church overbridge and also into Heartlands Parkway to avoid conflict with the River Rea Overflow Channel in Watson Road. Local topography suggests that in the event that this proposed infrastructure bursts, surface waters will be collected to the River Rea, its overflow/relief channel or the Grand Union Canal before any local business premises are affected. Where the Proposed Scheme passes under Aston Church Road there is a small risk of surface water interface should a pipe burst though the fall of the carriageway will convey surface waters away from this infrastructure.

8.4.11 No diversion is proposed to Washwood Heath and Bromford water mains and therefore no change in risk is envisaged from the water supply network.

Reservoirs/large water bodies

8.4.12 This section describes the potential risk posed in the event of a catastrophic failure of the reservoirs and other large water bodies in the vicinity of the Proposed Scheme. It is important to have awareness about the impact of the failure of reservoirs and large water bodies, as although the risk is low, the impact can be high.

8.4.13 There is no intention to impact on the structural integrity of the reservoirs/large water bodies at source and hence will not increase the risk of this occurring.

8.4.14 The Environment Agency's reservoir inundation mapping indicates potential flow paths for large quantities of water to reach the Proposed Scheme in the event of reservoir breach, which could have a significant impact on features such as the Bromford tunnel. However none of the features located are within 1.5km of the route.

8.5 Summary of potential impacts on flood risk

8.5.1 Reference should be made to the flood maps provided in Volume 5: Map book WR-05. A summary of main receptors is provided in Table 9.

Table 9: Summary of potential flood risk impacts in CFA26

Receptor	Vulnerability Classification	Pathway	Impacts
Proposed Scheme: General		Rivers	The route is located on embankment and viaduct. Embanked sections are in Flood Zone 1 and as such will not cause a significant increase in flood risk. Where the route spans Flood Zones 2 and 3 viaducts will be employed and following implementation of all mitigation measures no significant increase in flood risk is identified.
		Surface water and drainage systems	Flood walls to be provided to protect Proposed Scheme from surface water flow. Surface Water drainage network designed to maintain 0.1% AEP water level >1/0m below rail level.
		Groundwater	Bromford tunnel and east approach structure - suitable water-proofing will be provided to structure to prevent water inundation. Groundwater drainage will be provided to mitigate impacts of the structure on groundwater flow and level.
		Artificial Bodies	Flood waters released by the failure of the artificial water bodies identified in CFA26 are expected to flow along the River Rea and River Tame within the 0.1% AEP river flood extent. There will not be any increased risk of flooding from artificial sources caused by the Proposed Scheme
Proposed Scheme construction works at the Bromford tunnel west portal and vicinity of Washwood Heath		Rivers	No significant increase in flood risk up to the 1%plus CC AEP. Temporary works will be subject to inundation at events greater than 10% AEP.
Residential and commercial property upstream and downstream of the Bromford tunnel west portal	More vulnerable	Rivers	Subject to the correct implementation of all mitigation measures during construction of the Bromford tunnel west portal no significant increase in flood risk for events up to the 1% AEP plus CC in this area are predicted.

Receptor	Vulnerability Classification	Pathway	Impacts
Land adjacent to River Rea Overflow Channel	Less vulnerable	Rivers FZ3b	River Rea overflow realigned to avoid the Proposed Scheme. New relief/overflow channel will match existing performance; therefore no increase flood risk is identified.
Land adjacent to Washwood Heath Brook	Less vulnerable	River FZ3	Washwoood Heath Brook will be realigned to avoid new depot and tunnel portal. New channel designed to ensure depot and portal will be safeguarded from flooding and flood risk elsewhere is not increased.
Bromford tunnel western tunnel portal and approach	Essential infrastructure	Groundwater - High	Tunnel approach and portal within the superficial deposits, moderate (2m) change in groundwater level.
Receptors adjacent to River Tame	Less vulnerable	Drainage system	Surface water runoff increased from proposed scheme to be attenuated prior to discharge into River Tame. Part of increased runoff from proposed scheme will be re-used in rainwater harvesting system.
Washwood Heath deport - Severn Trent Water drainage network	Less vulnerable	Drainage system	Surface water runoff increased from proposed scheme will be attenuated prior to discharge into Severn Trent Water drainage network
Washwood Heath deport - STW drainage network	Less vulnerable	Drainage system	Affected Severn Trent Water sewer network will be diverted to avoid conflict with proposed scheme
Curzon Street station	Essential infrastructure	Drainage system	Existing Severn Trent Water drainage will be diverted to suitable locations. There will be no increase in flows except where proposed connections have been approved. Surface water runoff increased from proposed scheme will be attenuated prior to discharge into Severn Trent Water drainage network
Existing Network Rail track	Essential infrastructure	River	Crossing to be sized and replacement floodplains storage to be provided to ensure no change on flood level and flood risk due to Proposed Scheme.

9 Conclusions

9.1.1 This FRA accounts for the flood risk considerations caused by construction of the route of the Proposed Scheme within Washwood Heath to Curzon Street both to the Proposed Scheme and third parties.

9.1.2 River hydraulic model of the River Tame and the River Rea have been obtained from the Environment Agency. These have been updated and validated and used to determine the existing baseline flood risk posed by these watercourses for a range of return period flood events as well as flood levels up to and including the 0.1% AEP flood. This has resulted in the production of flood maps for the 5% AEP and 1% AEP +CC events which shown in WR-05 and WR-06 within the Volume 5 Map Book for Water Resources.

9.1.3 The Proposed Scheme has been incorporated into the existing baseline models in order for the impact of the proposals on flood risk to be determined.

9.1.4 The Proposed Scheme is being designed to be resilient up to and including the 0.1% AEP storm event. This is being achieved by either setting the rail level at 1m above the 0.1% AEP flood level or by protecting the route using flood defence structures set at a level that is equivalent to 300mm above the 0.1% AEP flood level.

9.1.5 Flood defence structures are required to protect proposed infrastructure to the south and east of Washwood Heath from inundation by the River Rea.

9.1.6 The area in the vicinity of the proposed Bromford tunnel has been identified as a location where the groundwater regime may be affected by the proposed design. Therefore initial conceptual and numerical modelling of the existing groundwater regime around the Bromford tunnel portals has been undertaken to establish the potential impact of the proposed tunnel on groundwater levels within the superficial aquifer deposits. The model predicts the Bromford tunnel west portal approach may have an impact on groundwater levels with a simulated ponding of groundwater on the southern boundary of 2m and a drawdown of groundwater on the northern side of 2m.This is in an area where water strike information indicates existing groundwater levels are between 2 and 5 m depth.

9.1.7 The initial groundwater modelling has indicated that there is the potential for the Bromford tunnel west portal to act as a barrier to groundwater through flow within the superficial deposits. However, it is recognised that the conceptual model and initial groundwater model are based on water strike data and that aquifer properties used are within the range of literature values but not proven on site. These important uncertainties will be investigated as part of the on-going design process to refine the conceptual and numerical model build properties.

9.1.8 Depending on the depth of groundwater proven from site investigation, the potential increase / drawdown on groundwater levels may result in a long term shallow groundwater level condition in areas adjacent to the portals. Suitable water-proofing will be provided to the structure to prevent water inundation. Groundwater drainage will be provided to mitigate impacts of the structure on groundwater flow and level.

9.1.9 The surface water management strategy for CFA26 ensures run-off generated by rain water falling onto the Proposed Scheme is collected, attenuated and discharged at a controlled rate. The strategy is designed to manage discharges generated by rain storm events with a 1% AEP plus a 30% increase in rainfall intensity to allow for changes in rainfall patterns due to climate change.

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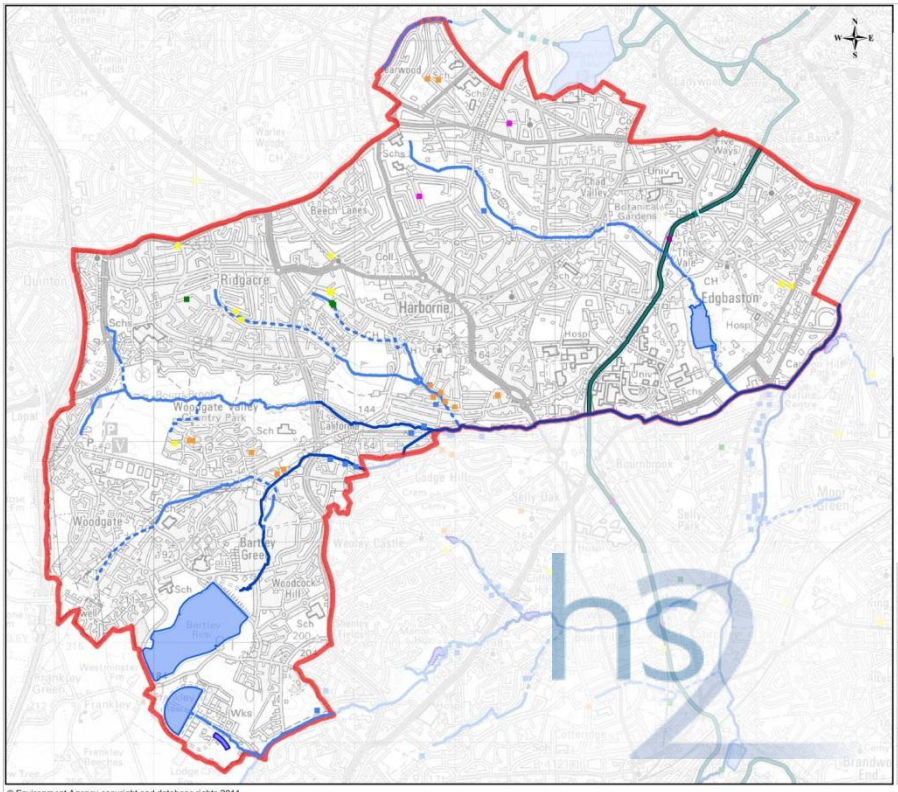
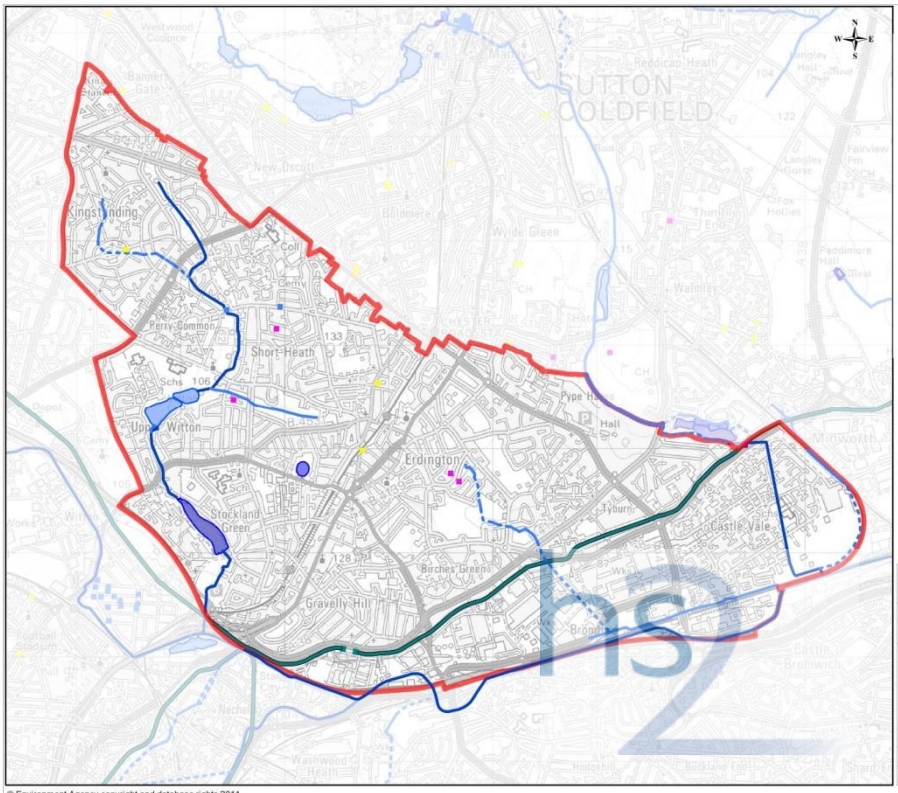
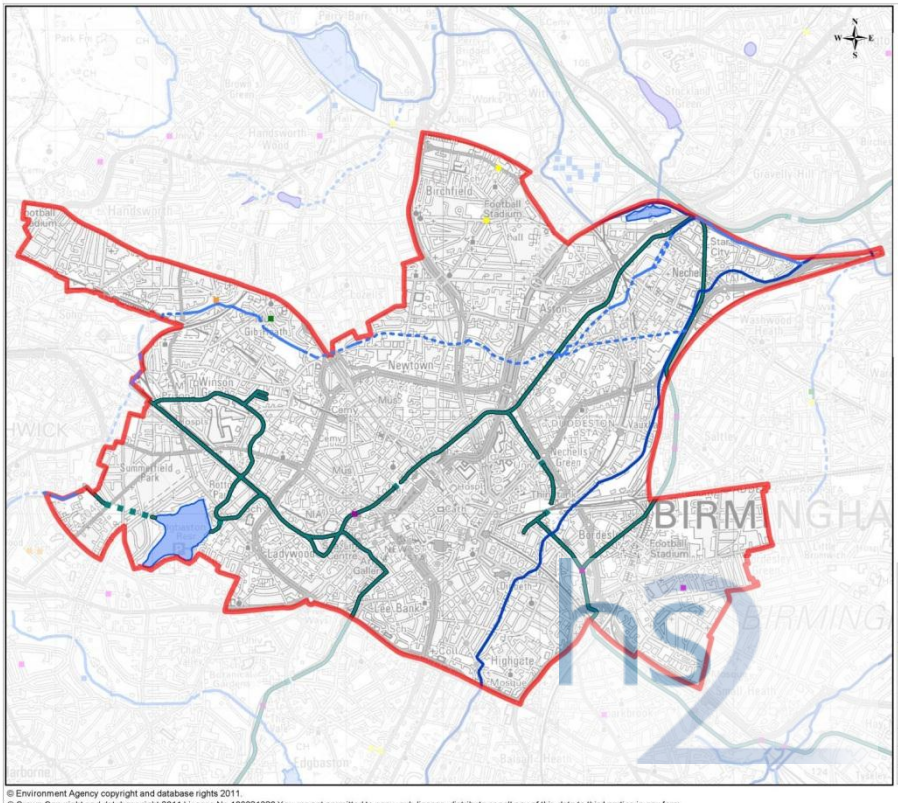
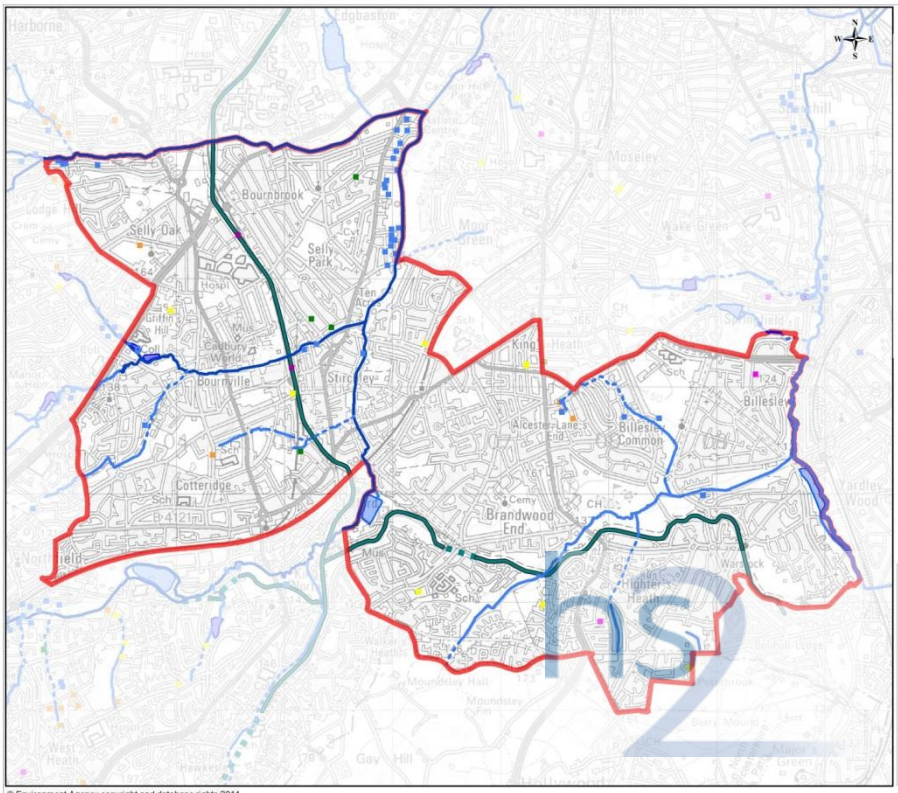
11 Annex A

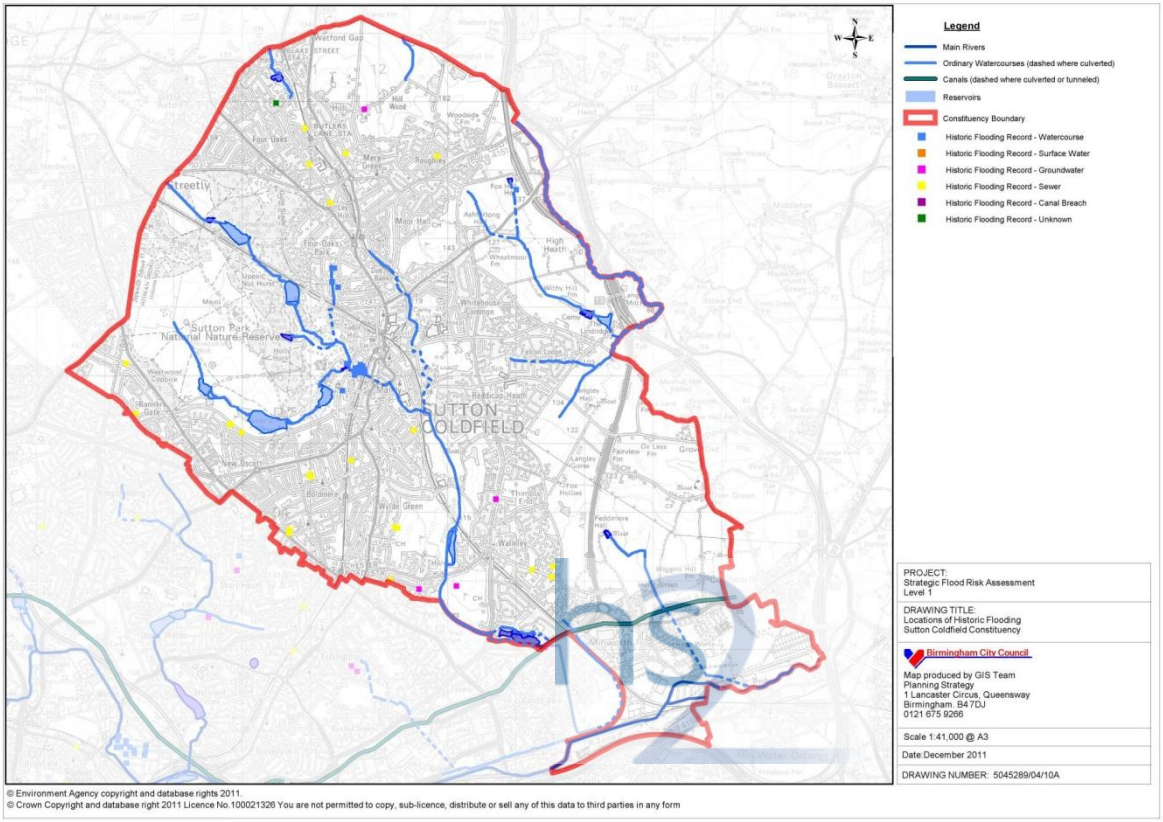
11.1 Birmingham City Council SFRM location of historic flooding and water features

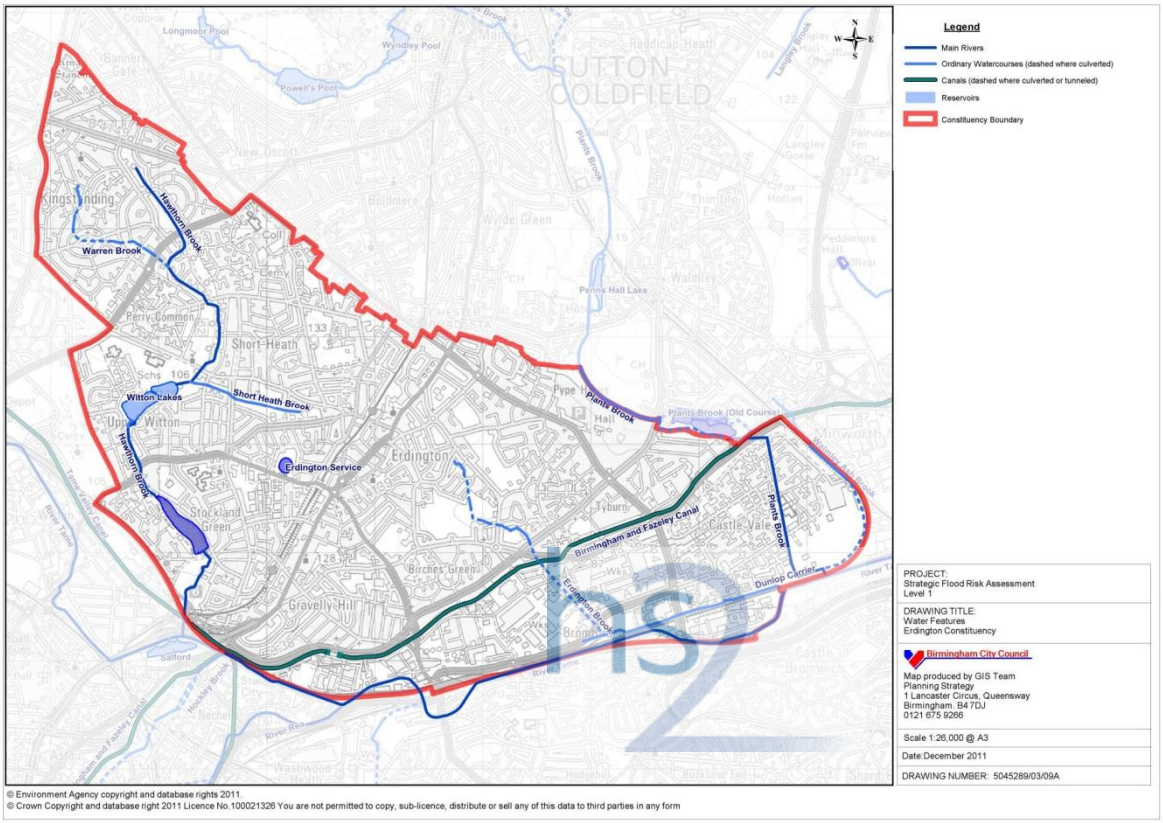


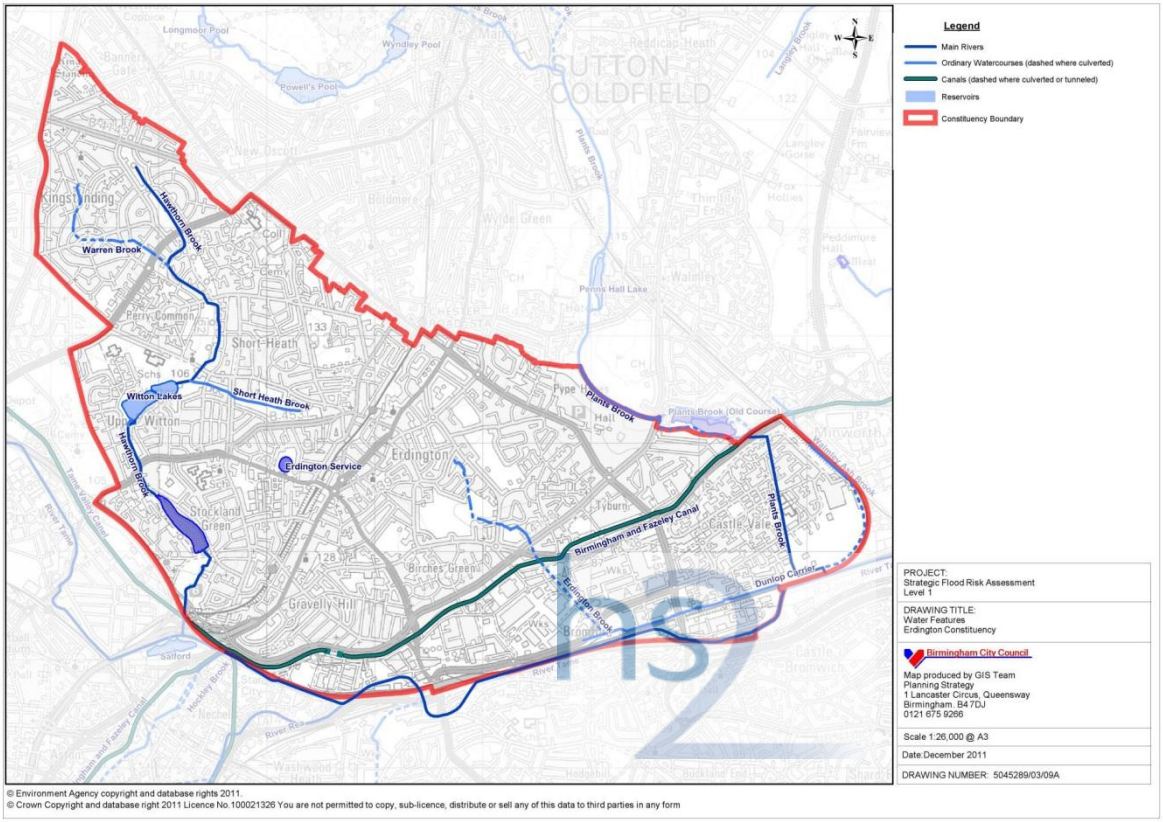


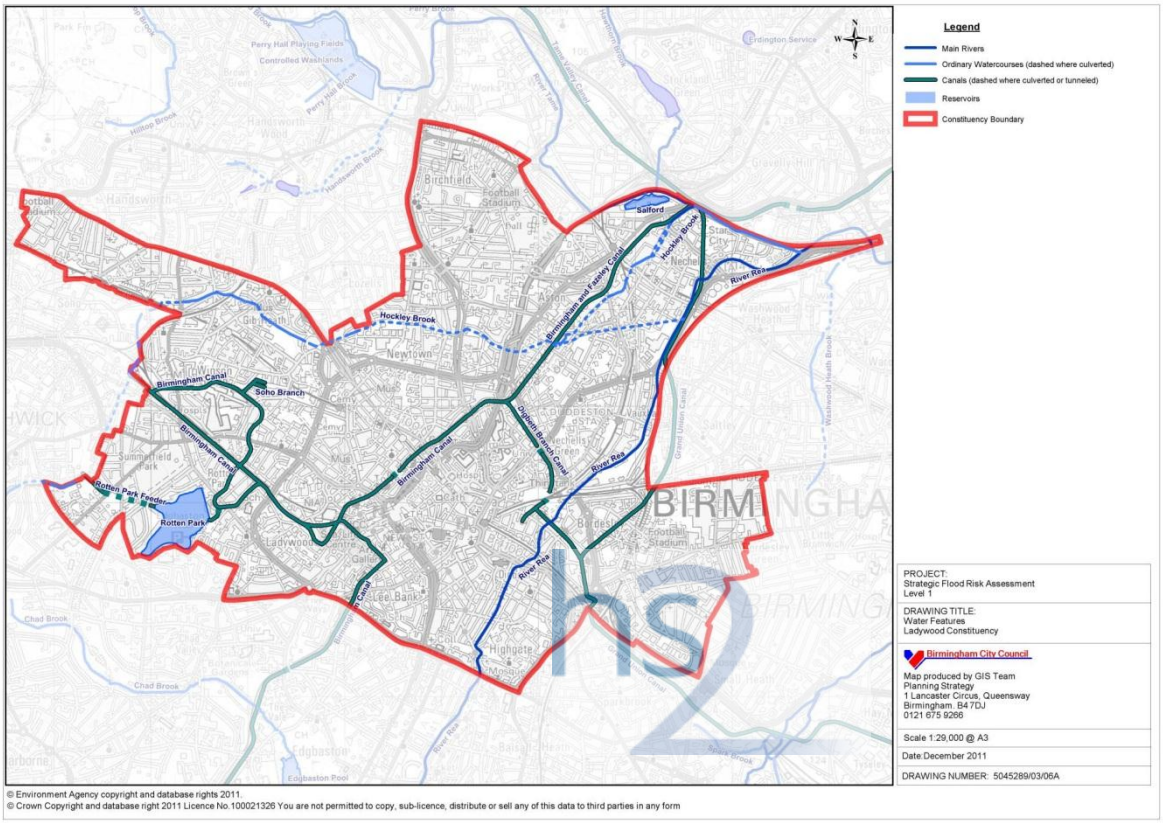


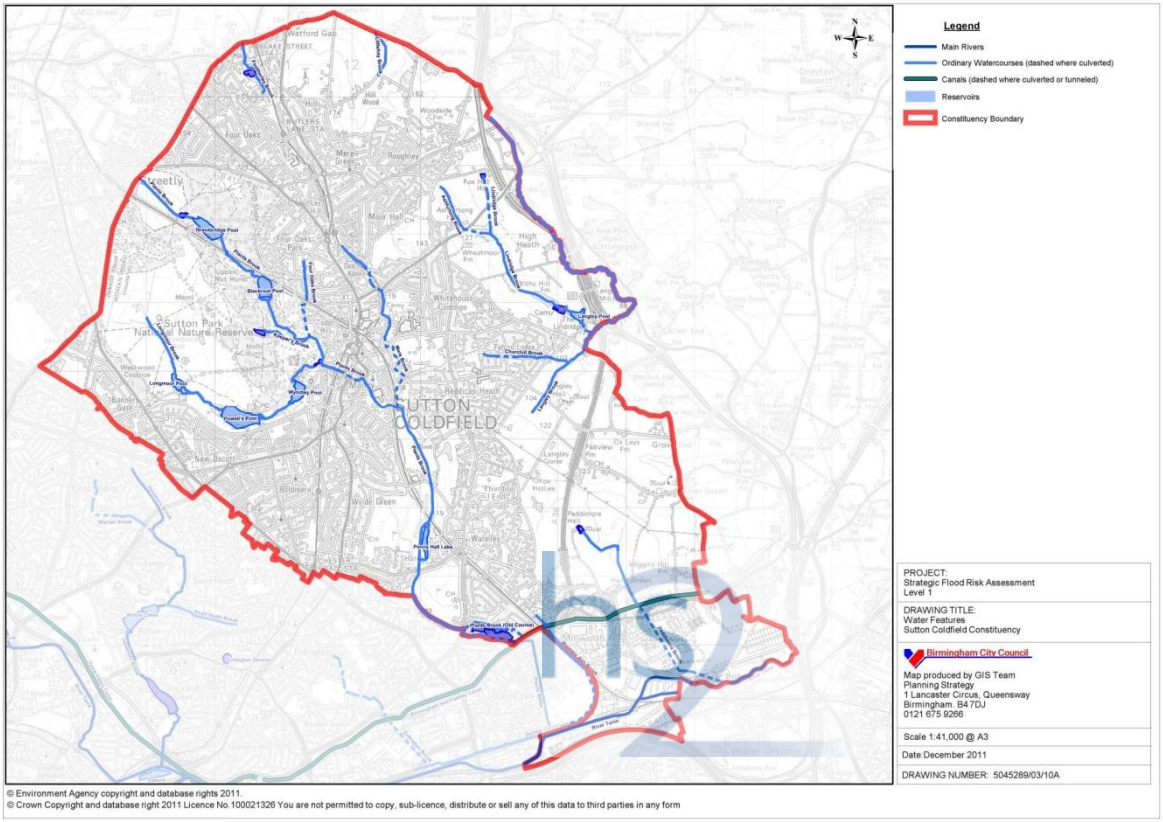


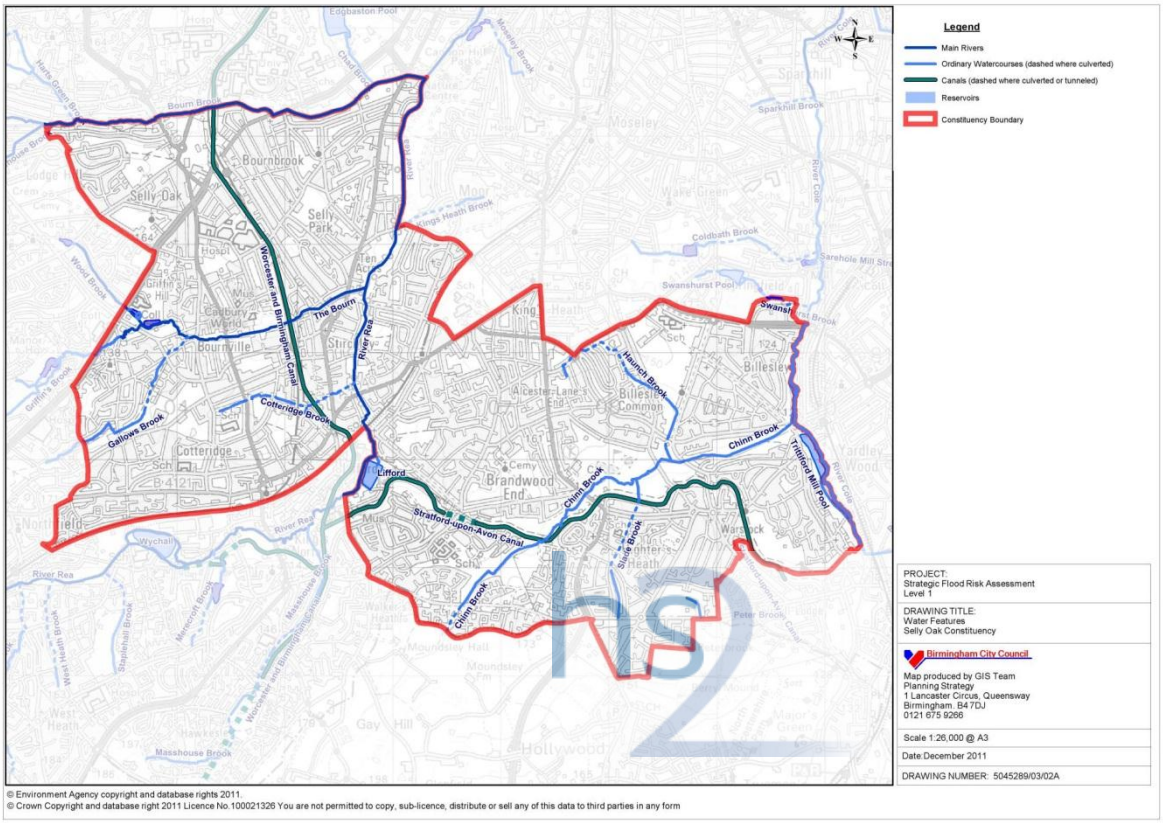






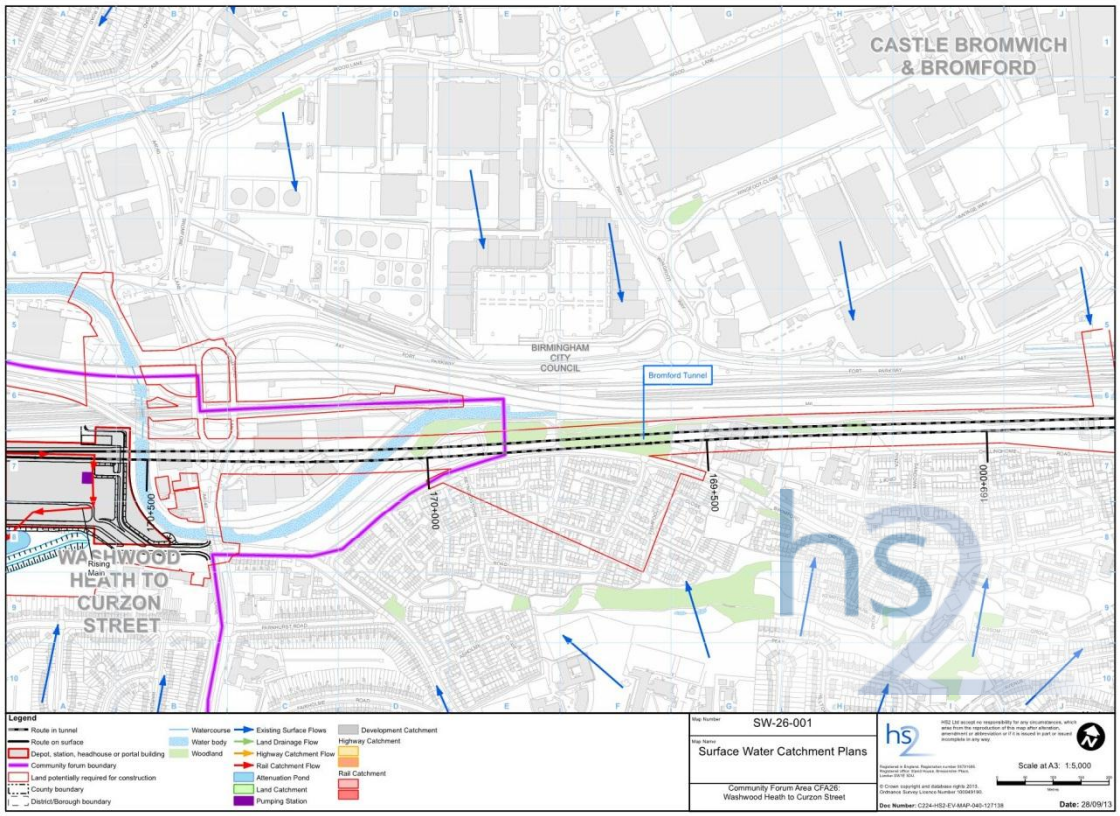


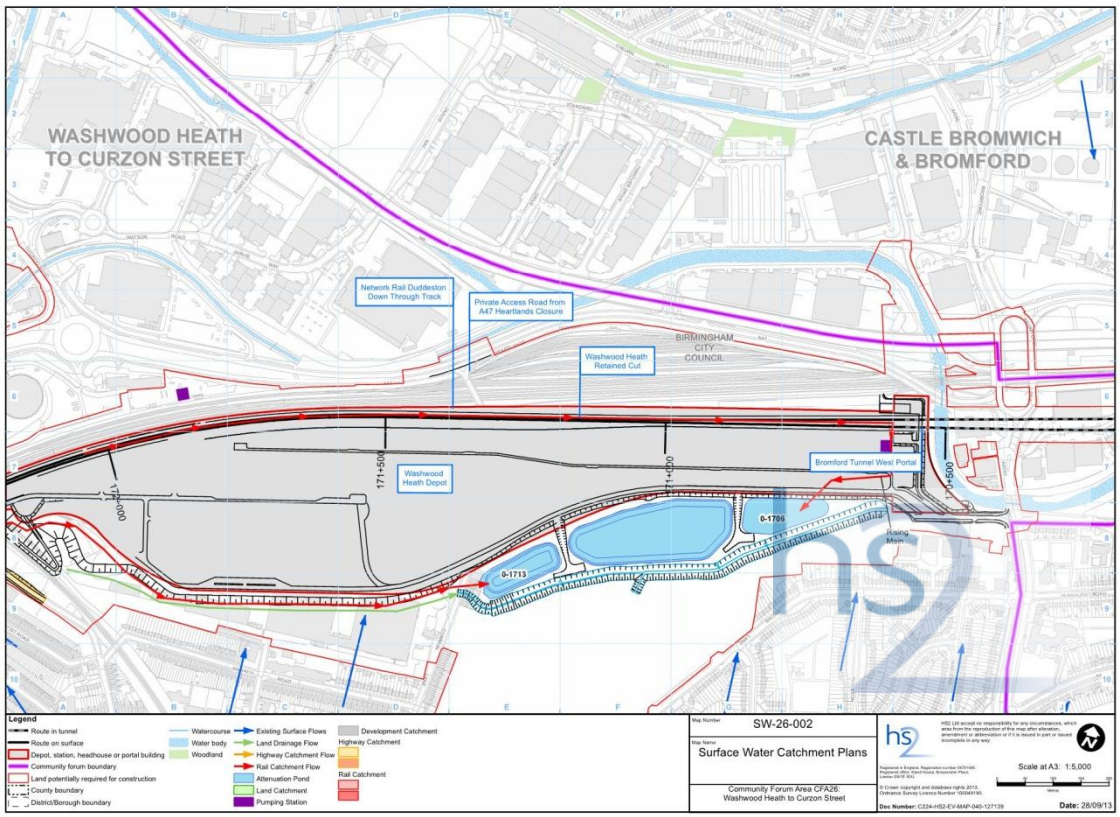


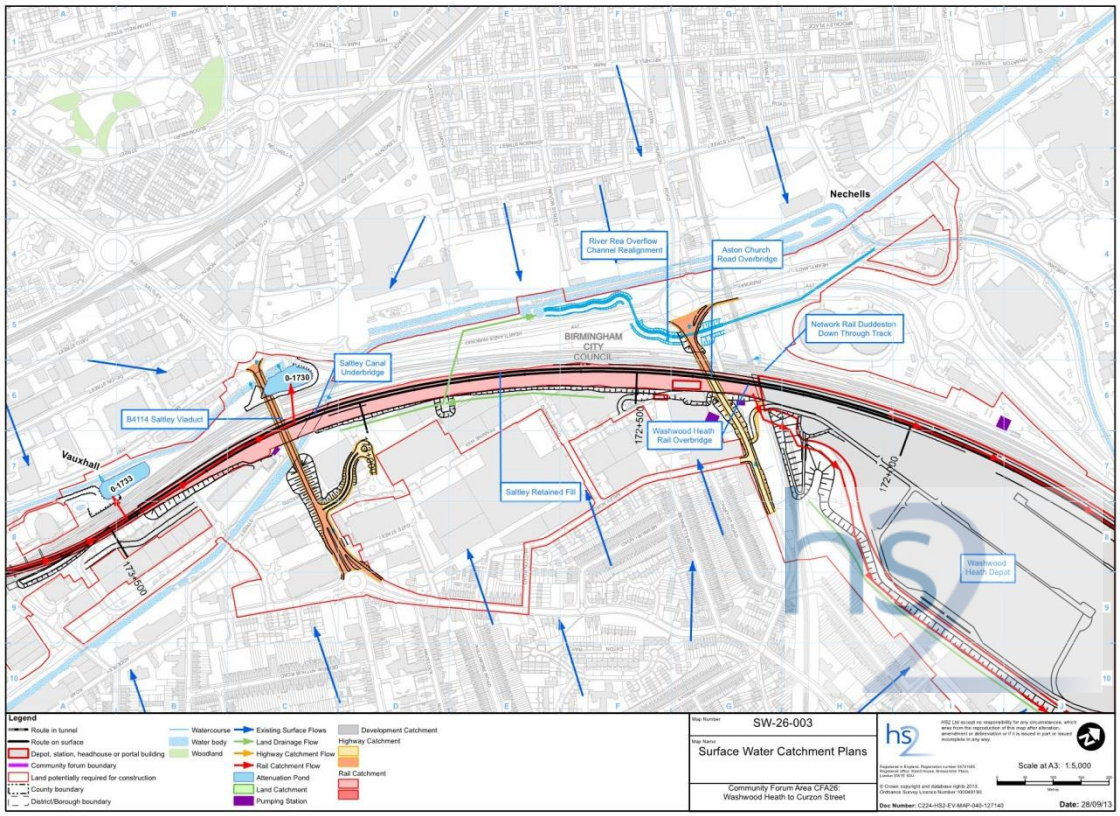


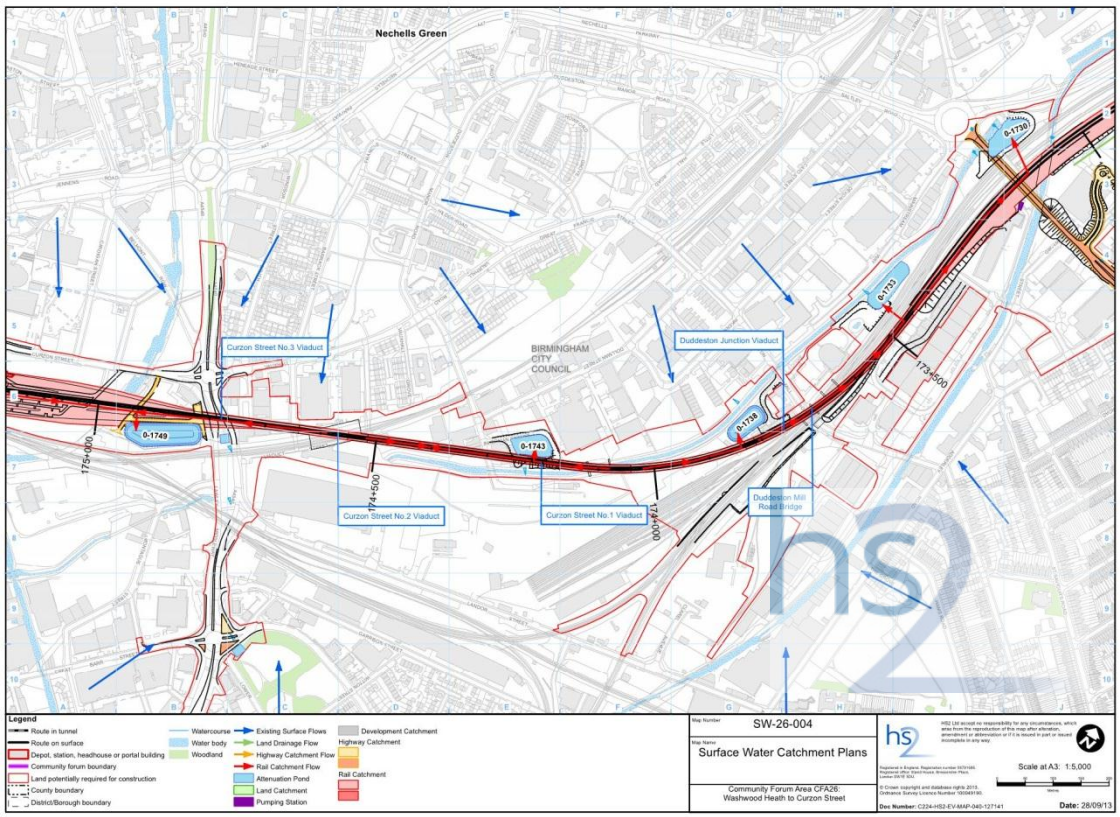
12 Annex B

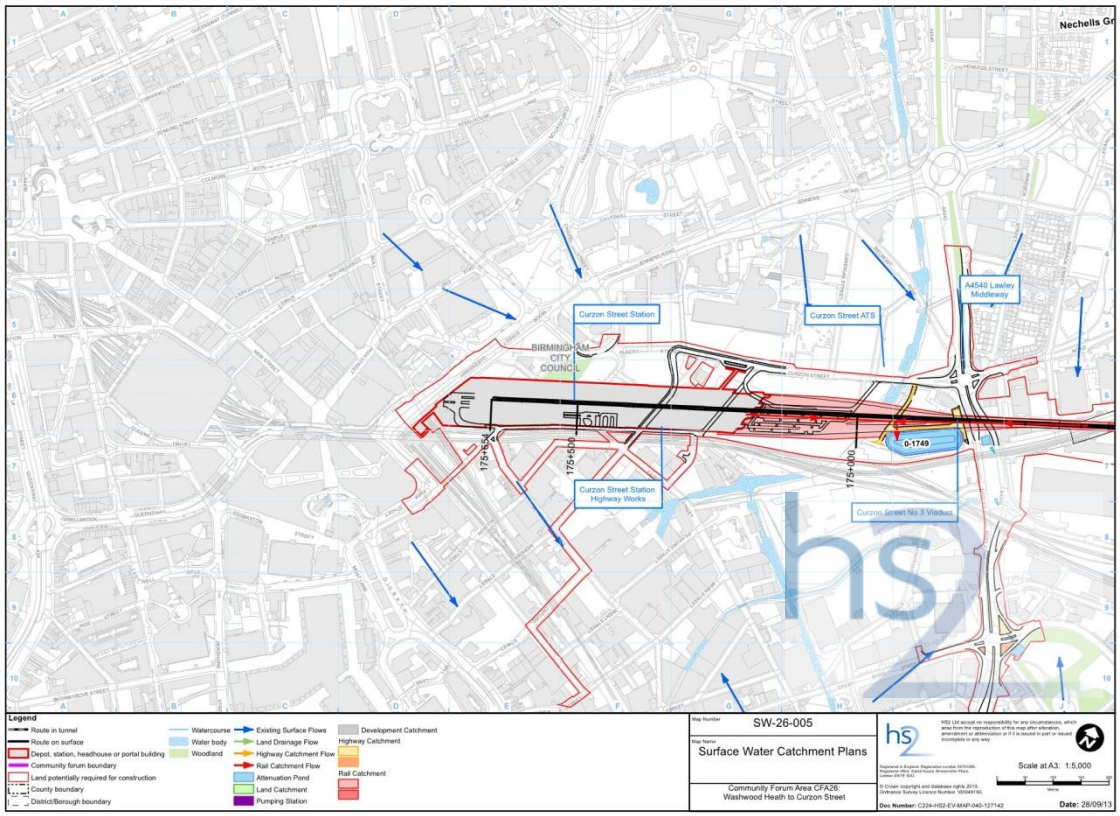
12.1 Surface water catchment flow figures


CASTLE BROMWICH & BROMFORD
BIRMINGHAM CITY COUNCIL
Bromford Tunnel
169+500
170+000
169+000
WASHWOOD HEATH TO CURZON STREET
Rising Main
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
Map Number
SW-26-001
Map Name:
Surface Water Catchment Plans
Community Forum Area CFA26: Washwood Heath to Curzon Street
Scale at A3: 1:5,000
Date: 28/09/13


WASHWOOD HEATH TO CURZON STREET
CASTLE BROMWICH & BROMFORD
Network Rail Duddeston Down Through Track
Private Access Road from A47 Heartlands Closure
Washwood Heath Retained Cut
BIRMINGHAM CITY COUNCIL
Washwood Heath Depot
171+500
171+000
170+500
Bromford Tunnel West Portal
0-1706
0-1713
Rising Main
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
Map Number
SW-26-002
Map Name:
Surface Water Catchment Plans
Community Forum Area CFA26: Washwood Heath to Curzon Street
Scale at A3: 1:5,000
Date: 28/09/13


Nechells
River Rea Overflow Channel Realignment
Aston Church Road Overbridge
Network Rail Duddeston Down Through Track
BIRMINGHAM CITY COUNCIL
Saltley Canal Underbridge
0-1730
B4114 Saltley Viaduct
Vauxhall
0-1733
172+500
Washwood Heath Rail Overbridge
172+500
Saltley Retained Fill
Washwood Heath Depot
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
Map Number SW-26-003
Map Name Surface Water Catchment Plans
Community Forum Area CFA26: Washwood Heath to Curzon Street
Scale at A3: 1:5,000
Doc Number: C224-HS2-EV-MAP-040-127140
Date: 28/09/13


Nechells Green
BIRMINGHAM CITY COUNCIL
Curzon Street No.3 Viaduct
Duddeston Junction Viaduct
0-1730
0-1733
173+500
0-1749
175+000
0-1743
0-1738
Curzon Street No.2 Viaduct
Curzon Street No.1 Viaduct
174+000
Duddeston Mill Road Bridge
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
Map Number SW-26-004
Map Name Surface Water Catchment Plans
Community Forum Area CFA26: Washwood Heath to Curzon Street
Scale at A3: 1:5,000
Doc Number: C224-HS2-EV-MAP-040-127141
Date: 28/09/13


Curzon Street Station
Curzon Street ATS
A4540 Lawley Middleway
BIRMINGHAM CITY COUNCIL
175+554
175+500
175+000
0-1749
Curzon Street Station Highway Works
Curzon Street No 3 Viaduct
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
Map Number
SW-26-005
Map Name
Surface Water Catchment Plans
Community Forum Area CFA26: Washwood Heath to Curzon Street
Scale at A3: 1:5,000
Date: 28/09/13